Army Air Defense

Introduction

During the Cold War the Soviet army air defense systems were dominant in conflicts with only a very few exceptions. Mostly these had chance to demonstrate their capabilities and they were the most numerous and widely used. Because of this factor using the Soviet and Warsaw Pact organization and equipment is explained the army air defense. The army air defense of other nations and the NATO are explained by comparing to the Soviet equipment and organization highlighting the main conceptional and other differences.

For understanding the different level of air defense and equipment it has to explained at least generally the structure and organizational level of the armies. There can be minor or even major differences between nations in organizations. For example some armies uses army-corps-brigade-battalion some use army-division-regiment-battalion structure. The unit size of the different kind of units on the same level is not the same there are huge variations all around the world. Sometimes specific equipment types are assigned on different level or totally different branch of the armed forces. Some of these interesting exceptions will be shown with exact examples.

The point of this chapter is not fully explain the organization levels and equipment every armies in the world. The point is to get such an overview about the structure and organization which helps to understand the unit size, role and quantity of layered air defense and design philosophy behind them. As an off design effect it helps to understand any armed forces of the world.

In the attachments is the **FM 100-2-3 The Soviet Army – Troops, organization & equipment** document[1] which explains with great detail the structure of the Soviet Army. Very likely the document is not 100% accurate – especially it is based on intelligence information – but because of its size and detail it is a very useful document for a general overview. The content below is strongly based on FM 100-2-3 but also other sources were used as well as the knowledge base of the lectors and co-authors who participated in the creation of this summarizing document. It is also available another source the **FM-100-60 Armor- And Mechanized-Based Opposing Force.** It is basically the reviewed later version of the FM 100-2-3 but instead regiment system it uses the brigade system and it got some minor terminology corrections.

In the footnote below[2] is explained the structure and organization of a World War II German tank division. It is very good representation the hierarchy of a division with basic terms. The Cold War Soviet organization is very similar to the shown German. Of course as the technology became more advanced and SAMs appeared as support units instead air defense guns and the “combat” battalions got more diverse equipment. Understanding the conception of different levels in the video strongly supports to understand the later explained topics.

On the following page the chart explains the unit sizes in general in the armies all around the world. On the Wikipedia[3] is also available a similar table. The values do not exactly overlap but both are usable for a general overview. [4]

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1 http://fas.org/irp/doddir/army/fm100-2-3.pdf

2 https://www.youtube.com/watch?v=rk-T-iNSdaw

3 https://en.wikipedia.org/wiki/Military_organization#Modern_hierarchy

4 *The table is created by Oszkár Kecskeméti.*

unit level	*size/manpower*	*sub unit quantity*	*commander*	*note*
squad	3-15	smallest unit	sergeant / staff sergeant	
platoon	30-50	2-5 squads	2nd / 1st lieutenant	
company	75-200	3-5 platoons	1st lieutenant, captain rarely major-	*for artillery and air defense units battery term is often used*
battalion	400-800	3-5 companies	major	
independent battalion	400-800	3-5 companies	lieutenant colonel / colonel	
regiment	800-2000	3-5 battalions	lieutenant colonel / colonel	*for air forces wing (USA)/regiment*
brigade	2500–5000 (11000*)		colonel / brigadier general	*It is a larger and more flexible unit than regiment, subunits can be either battalion or regiment. Similar in role to regiment but it is (much) larger unit.* **In Austria and Swiss brigades are division size units*
brigade battlegroup	4000–5000		colonel / brigadier general	*In international (peacekeeping) or similar operations are used but not regularly, in the US Navy is called Regimental Combat Team (RCT) in USMC-is called Brigade Combat Team (BCT); they are literally strengthened brigades*
division	10 000–15 000	2-4 regiments or brigades	brigadier general / major general	*It is capable for longer perform combat operations as a standalone unit.*
corps	25 000–60 000	3-5 brigades or division	brigadier general / Lieutenant General	*It is roughly equivalent with army but it is a smaller size unit but it is not commonly used. Depending of the equipment quantity and personnel smaller level units can be assigned into a corps or army*
army, field army	40 000–200 000	3-8 divisions mixed with brigades and regiments	Lieutenant General / Colonel General	*Armies mostly has strategic goals. The army can contains occasionally corps but in general it is built up from division, (support) brigades and regiments.*
army group	400 000– 1 500 000	3-6 armies	Lieutenant General / Colonel General / Marshal	*Highest level unit in peacetime.*
Front/Theater	400 000– 1 500 000	varied	Army General / Marshal	*The front in Soviet / WPACT existed only in wartime. Highest level unit.*

Most of WPACT (Warsaw Pact) member states used the same unit hierarchy system as the Soviet Union except Bulgaria. The Soviet Union and all WPACT state used the army-division-regiment-brigade, the "triad" system Bulgaria was the only exception.

In the "triad" system from divisions is built up an army. A division consists three regiments, one regiment contains three battalions and so on. It has to be underlined this concerns only for the "core combat" units. (Will be easier to understand through exact examples.) Bulgaria and Hungary from 1987 used the "quadruple" system. In that system instead divisions the army is built up from corps and corps is built up from brigades. One brigade consists four battalions and one battalion has four companies.

Because the document explains the army air defense from mid-late '60s in Soviet Army the "triad" system is used every time with comments where it is necessary to explain the main differences between in quality and quantity for NSWP[5] countries.

Structure & Organization of the Soviet Army Air Defense

Because of the sheer size of an army and a theater a front commander is not able to keep everything under his personal control. He has to rely on their subordinates to executing the orders from the highest level down to the squad level. The quantity and the commanding capability of the air defense systems were designed according the structure of the Soviet Army.

In the Soviet combined army conception the smaller maneuvering unit was the battalion. It meant this was the lowest level where a unit had equipment against any kind of targets (IFV, tank, helicopter, airplane, artillery) even it was not the top level category weapon.

A single battalion against airplanes and helicopter had (from late '60s in the Soviet Union) MANPAD (such as Strela-2/SA-7 Grail) against tanks anti-tank guided missiles (ATGM, in the '80s such as the 9M113 Konkurs/AT-5 Spandrel). The infantry had another anti-tank or anti-vehicle weapons such as the famous RPG-7 and portable recoilless rifle (such as SPG-9). Some recoilless rifle and ATGM also were mounted on vehicles. Besides these weapons the support units of the combat battalion[6] can strongly amplify the effectiveness of the battalion but this depends on the level of support unit. For example artillery support can be a 82 mm mortar or even a 155 mm artillery battery.

Because of the focus of the document the explanation of the organization and structure does not go lower than battalion level because it is unnecessary. In the "classical triad" system two main types of the battalions were categorized; mechanized rifle infantry and tank (armored) battalion. This kind of categorization goes up to division and even more until army level therefor exist tank regimen and mechanized rifle infantry division, etc.

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5 *Non-Soviet Warsaw Pact member*

6 *In combat units term we understand the units which engage the enemy within visibility range which mainly consists tanks, APCs, IFVs, infantry, ATGM capable vehicles. Every other units are classified as support unit such as radio technical or medical units but are also exist combat support units such as artillery or air defense units.*

In English terminology we can be found '*motorized*' and '*mechanized*' terms which sometimes are confusing and are not used properly. Motorized infantry is transported by trucks or any **other unarmored motor vehicles**. It is distinguished from mechanized infantry, which is carried **in armored** vehicles such as armored personnel carriers or infantry fighting vehicles. The last category is light infantry which can typically operate autonomously from supporting elements and vehicles for relatively long periods and may be airborne.

The linked FM 100-2-3 The Soviet Army – Troops, organization & equipment uses motorized rifle battalion term from both BTR (wheeled) or BMP (tracked) type vehicle equipped units which is not accurate. On every diagram which originated from FM 100-2-3 the "*motorized*" has to be considered as "*mechanized*" in current document during the following explanations. The FM 100-60 uses the right terminology.

Regardless of these the current document uses as source also the FM 100-2-3 because it contains information about the personnel of the units. In general both sources give the same information about units from battalion up to army level.

In some cases on the Internet can be found such comments or articles where being wheeled or tracked determines the classification which is also not accurate. A unit is not motorized because it has BTR-60 wheeled APC and it is not mechanized because it uses M113. Both are mechanized units because both vehicles are armored.

The composition of combat units from battalion levels are the following:

Battalion:

- One armored battalion consists 30+1 main battle tanks (MBT), the +1 is the battalion commander vehicle.
- One mechanized rifle battalion consists about 40-50 armored personnel carriers (APC) or infantry fighting vehicles (IFV) including two commanding vehicles.

Regiment:

- One **armored** regiment consists three **armored** battalions, 3x31+1 main battle tanks (MBT), the +1 is the regimental commander vehicle. The nominal tank quantity is 94 pcs.
- One **mechanized rifle** regiment consists three **mechanized rifle** battalions, with about 120-150 APCs/IFVs and 30+1 tanks.

Besides the upper listed units the mechanized infantry regiment also had amphibious PT-76 light tank but in the recon company of the regiment as combat support unit. The firepower and armor thickness of the PT-76 light tank is not comparable on any level to main battle tanks (MBTs such as T-54/55/62/70/80) because their role and position in the structure are different. Their firepower and protection is designed accordingly to deal with weaker recon units.

Division:

- One **armored** division consists three **armored** regiments (and one mechanized rifle regiment as support combat unit in reserve).
- One **mechanized rifle** division consists three **mechanized rifle** regiments (and one armored regiment as support combat unit in reserve.)

It is very important to understand the core of the divisions the combat regiments of their type. The core combat capability of a tank division established by the tank regiments, same case are the mechanized

regiments for the mechanized divisions. These provide the direct firepower. The another regiments, battalions, companies, etc. in the division are supporting the long term effectiveness and flexible usage of the division. Already a mechanized rifle battalion has combat support units for example the mortar battery ,anti-tank platoon or signal platoon.

On regiment level also exist signal unit but on this level we are speaking a larger support unit, there is signal company instead signal platoon. The fire support is given by not a (82 mm) mortar battery but 122 mm artillery battalion (for with 2S1 Gvozdika).

On division level the recon unit is a recon battalion, the fire support unit is artillery regiment (which can be self-propelled 152 mm 2S3 Akatsiya or rocket artillery either) and instead MANPAD capable air defense platoon for the division is assigned a whole air defense regiment for example SA-6 regiment for an armored division.

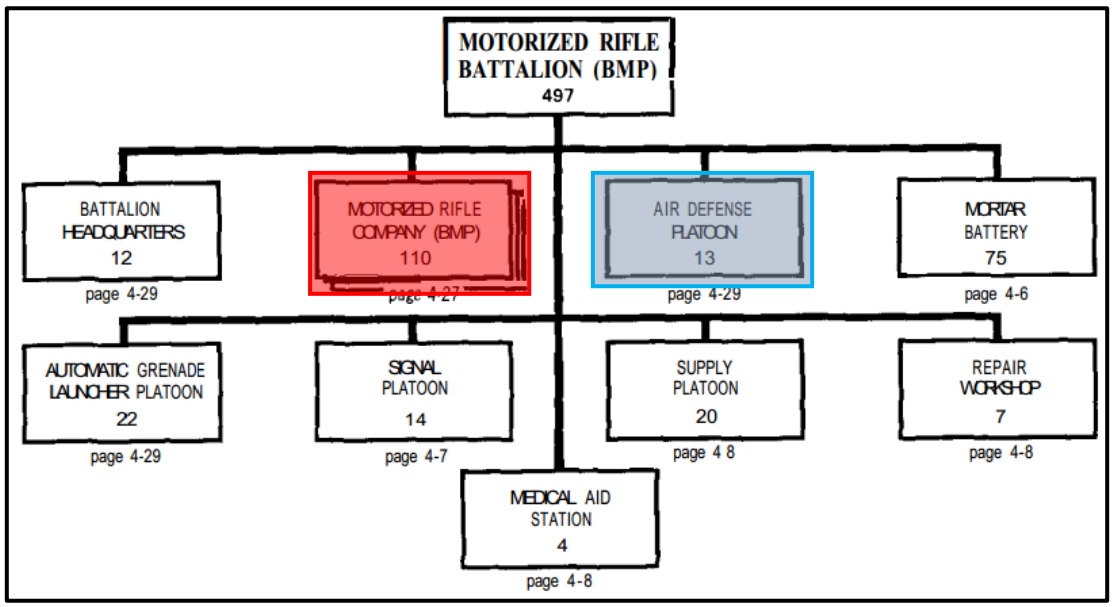
The size of the support units as grow as the supported units become larger but the size of the support unit is at least one level lower (artillery regiment of the division) and sometimes two (recon company of the motorized rifle regiment) or sometimes ever smaller comparting to the supported unit.

The size of combat units comparing to similar organizational level support unit is much larger. For example the personnel of a mechanized rifle regiment is higher comparing to an air defense regiment. A mechanized rifle platoon is larger than a MANPAD equipped air defense platoon but their sizes are more or less comparable. Through exact example; the personnel of a tank regiment is about 1600 men while a 9K33 Osa (SA-8) or 2K12 Kub (SA-6) air defense regiment has only about 500 men regardless both units are regiment.

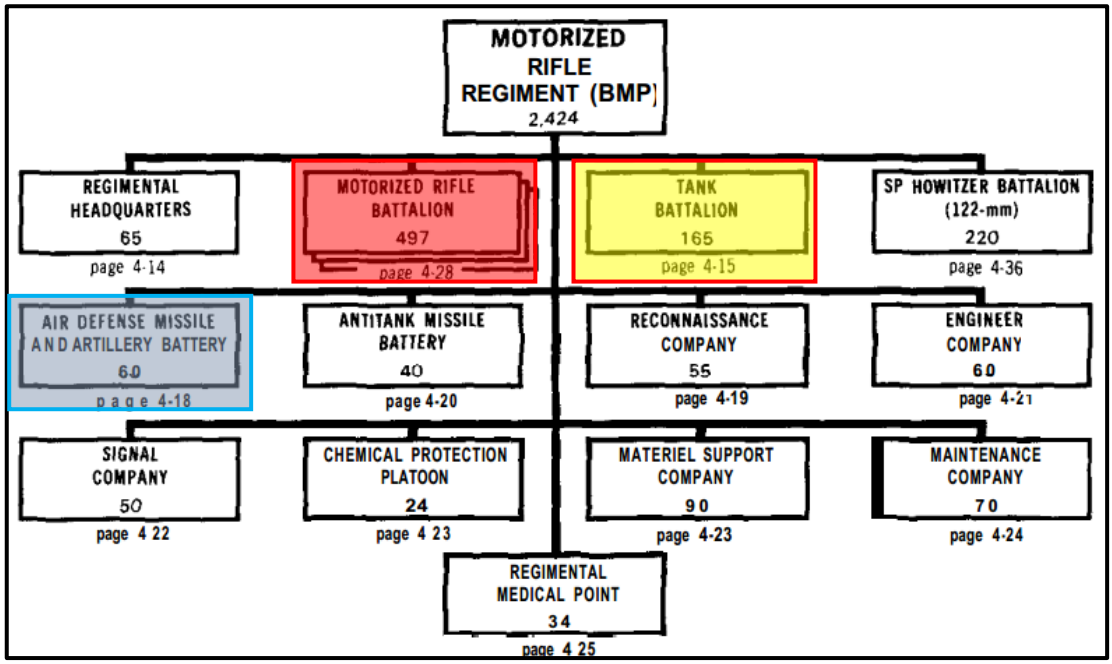
In the FM 100-2-3 The Soviet Army – Troops, organization & equipment document and also in the FM 100-60 are shown the mentioned units above in very detailed form using charts and diagrams. In current document only some of them are used to illustrate the layers of the army air defense of the WPACT.

Hopefully following the explanation below will be easier to understand the very large and complex Soviet army air defense and the structure and organization levels of the armed forces as well as the air defense of some other nations.

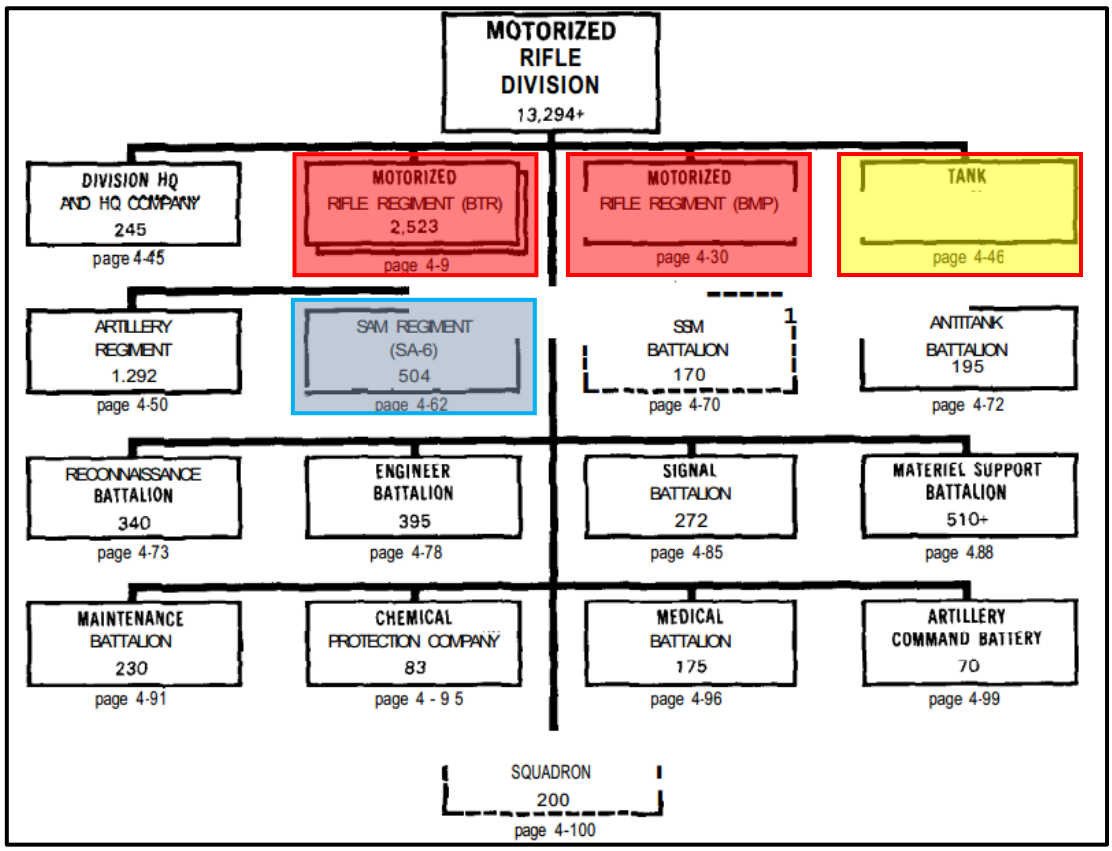
On the chart below are shown the elements of the mechanized rifle battalion. With red is highlighted the combat units the three mechanized rifle companies with 3x110 personnel. With blue is highlighted the single air defense platoon with MANPADs. We can see the support units of the battalion is on platoon size level except the mortar battery. About 60% of the total personnel of the battalion are in the three mechanized rifle companies.



On the chart below are shown the elements of the mechanized rifle regiment. With red are highlighted the combat units the three mechanized rifle battalions. The role of the yellow marked single tank battalion will be explained later, it will be crucial. The air defense component is the air defense missile battery (highlighted with blue). The support units of the regiment is generally one level higher comparing to a battalion. From the total 2 424 personnel 3x497 is part of the rifle battalions. About 61% of the total personnel are in the three mechanized rifle companies.



On the chart below are shown the elements of the mechanized rifle division. With red are highlighted the combat units. Two mechanized rifle regiments with BTR (wheeled) and one with BMP (tracked) equipment and one reserve tank regiment of the division.

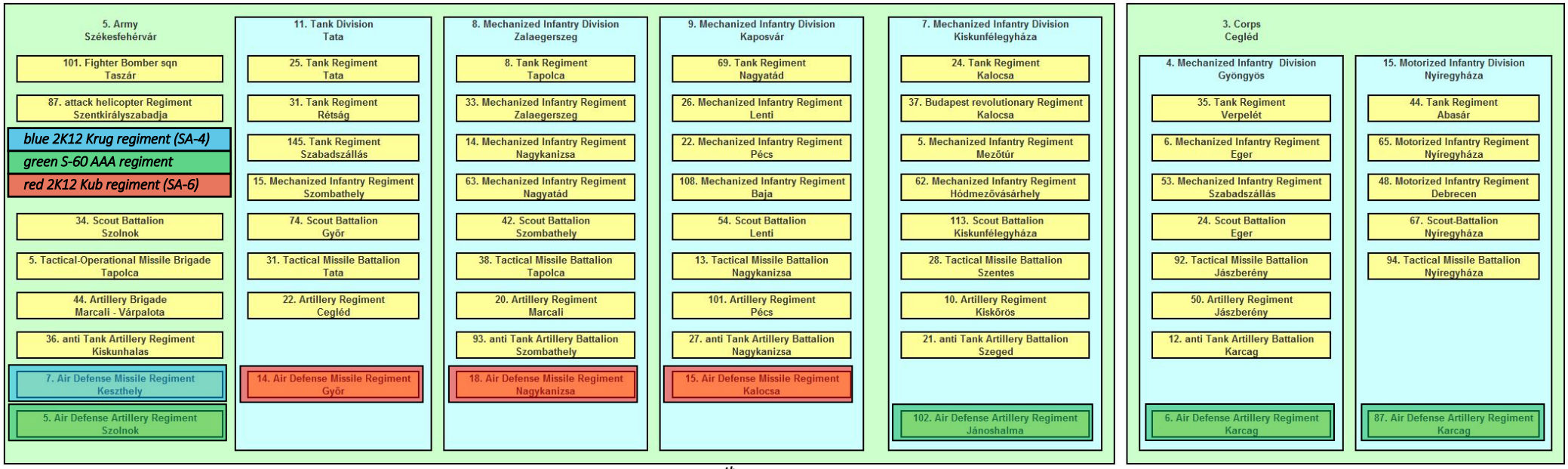


The air defense regiment of the division is highlighted with blue (SA-6 / 2K12 Kub). The support units of the division are generally one level higher comparing to a regiment. About 37% of the total personnel of the battalion are in the three mechanized rifle regiments. The personnel of the mechanized rifle regiment is 2532 men. Even if the personnel of the reserve tank regiment (1143) is added ratio is still only 45% (it is listed elsewhere in the FM 100-2-3).

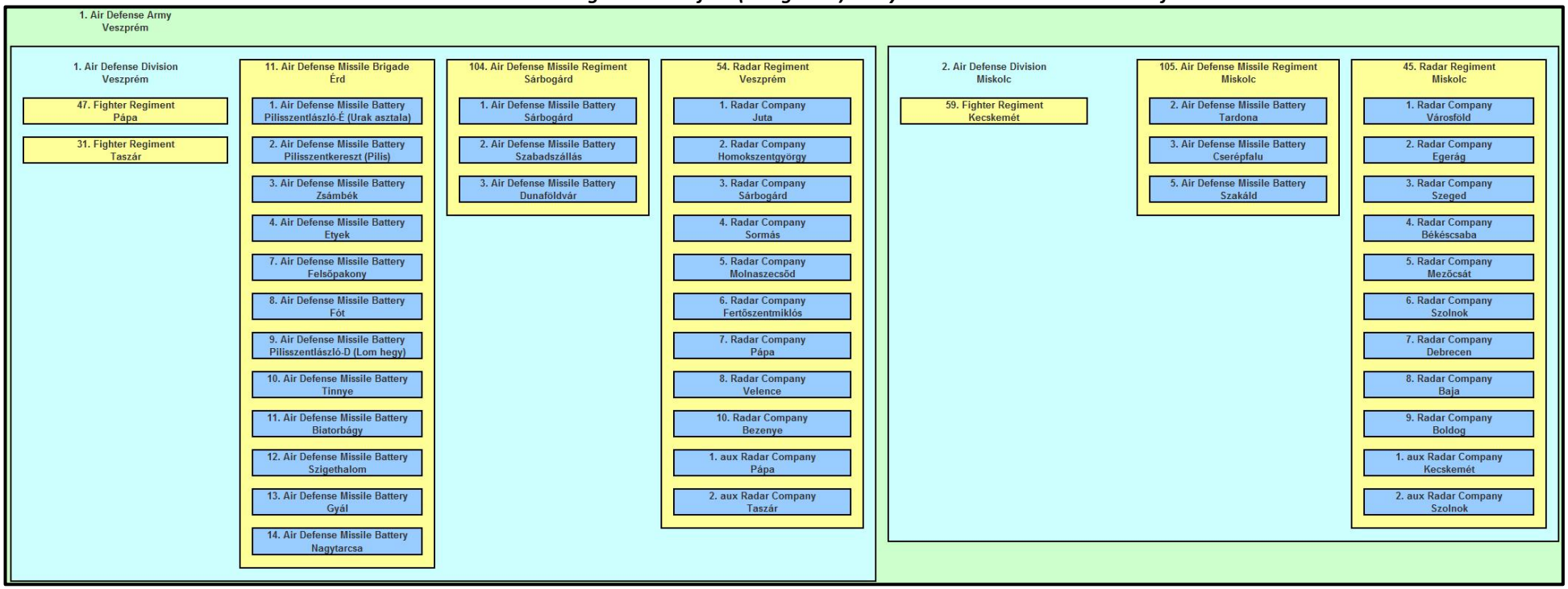
For higher level units the ratio between combat/support units can be even lower because more and more are in the army or in the army group from the latter. For armies and army groups (front level) even special divisions and brigades are available such as airborne and paratroop units as well as fighter, attack airplane and helicopter units.

One combined mechanized rifle army consisted 3-4 mechanized rifle divisions and 1-2 tank divisions. One combined tank army consisted 3-4 tank divisions and 1-2 mechanized rifle divisions.

On the following page is the structure and organization of the Hungarian People's Army in 1986. It is very useful for understanding the system of the Soviet Union and the NSWP countries. It is good not only for illustrating the structure and organization but is also for showing differences in equipment. We can see on the diagram the combat regiments: mechanized (rifle) infantry, tank and motorized (rifle) infantry. Besides these some larger combat support units are shown such as artillery regiments, scout battalions and air defense missile and artillery regiments.



Above the structure and organization of 5th (Hungarian) Army below is the homeland air defense.



It also has to be understand in wartime the armies would be composed from both Soviet and NSWP forces. For example in Hungary the following units would provide the component of the two armies of the army group:

Hungarian People's Army (Magyar Néphadsereg)	Southern Group of Soviet Forces (SGSF) Южная Группа Войск (ЮГВ - YuGV)
11th tank division (Tata)	13th tank division (Szentkirályszabadja)
8th mechanized division (Zalaegerszeg)	19th tank division (Esztergom)
9th mechanized division (Kaposvár)	254th mechanized division (Székesfehérvár)
7th mechanized division (Kiskunfélegyháza)	93th mechanized division (Kecskemét)
15th mechanized division (Nyíregyháza)	30th mechanized division (Zólyom)
4th motorized division (Nyíregyháza)	

In total were 11 divisions which would built up the army group with 2x5 divisions plus the reserve tank division of the army group. Likely the tank division at Szentkirályszabadja was the reserve but some sources suggest otherwise and consider the Soviet division in Ungvár as reserve unit. In the West Germany – East Germany – Czechoslovakia direction the army group would consisted three armies with two mechanized rifle armies and one tank army.

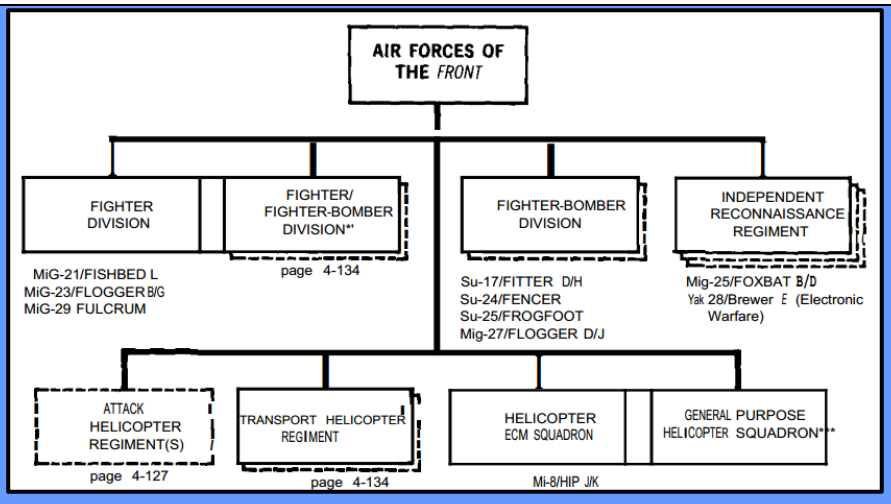
Because of the explanation above is now clear why pointless to consider only first line Soviet force alone in a NATO vs WPACT analysis. NSWP and Soviet forces in a real conflict would formed army groups as joint force under Soviet command and none of them would operate alone. This mixed army composition strongly changes the result of theoretical calculations of the combat potential on a section of a frontline. Both quality and quantity of the equipment of the NSWP countries were behind to Soviet forces literally in every cases if we compare first line (Category I) units. These issues will be addressed following the illustration of **the nominal Soviet force composition** then the following force calculations.

Everything above is a very idealized composition as baseline but in reality the army composition can be much more flexible. During the invasion of Afghanistan (1979-80) the 40th army consisted only three mechanized rifle divisions without a tank division. Therefore as a quick replacement from the central reserve from Belorussia was assigned an airmobile division and also got many combat support units besides the regular ones (with five independent brigades and four independent regiments within the army). Later the missing tank division was added but the airmobile division was removed and only two independent brigades and three regiments remained as support in 1982.

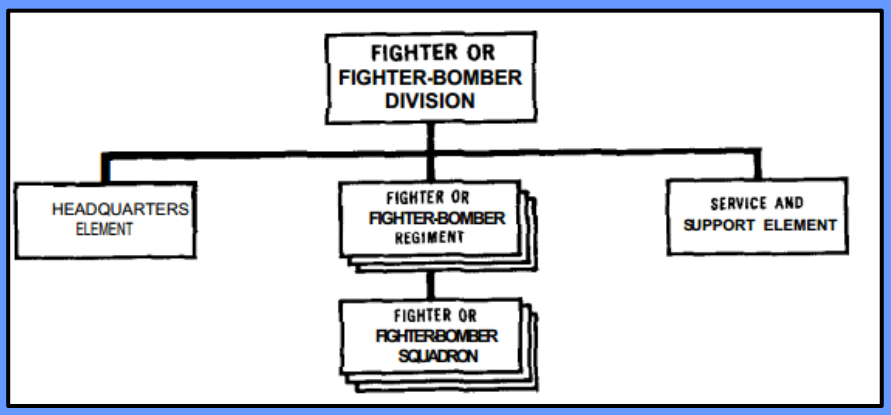
Regardless of unique issues and other factors the current document **always considers five division armies** because most of sources suggest this is useful generalization for understanding the quality and quantity of air defense. The point of the whole chapter knowing a standard idealized case and every other can be derivate from this state.

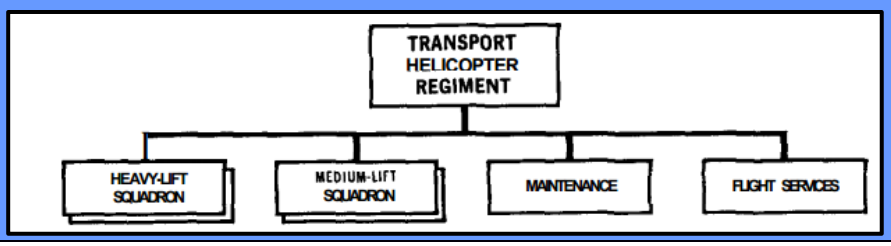
The FM 100-2-3 explains the unit composition up to the army group (front) level. On the page 162 we can see how large and complex is the composition of army group (front). Because of the content of other chapters about military aviation the air force organization is mentioned here.

The air power of an army group consisted typically 3-5 fighter and fighter bomber divisions besides the independent recon and electronic warfare regiment. A transport helicopter regiment also was part the air component with the electronic ECM squadron. In some cases besides the assigned combat helicopters to the division the army group itself also could have attack/combat helicopter regiment.



A fighter/fighter bomber division in general was built up from three regiments, one regiment consisted three squadrons. The inventory of a single squadron was typically 15-18 airframes (with 3-4 two seater non-combat capable trainer aircraft per squadron.) Considering all factors the aviation force of an army group could be anywhere between 350-750 fixed wing aircraft. The inventory of the heavy transport helicopter regiment was Mi-6 or Mi-26, the medium transport helicopter they was Mi-8/17 from the '70s. The nominal size of the regiments were 24/32 airframes depending on the type and size.





Another factor which makes difficult to explain the capabilities the transitional periods. A part of previous generation weapon systems still were used while a part of them already had been replaced with a new system. This happened in the USSR army and also in the NSWP countries with a 5-10 year time shift and delay. Comparing to nominal Soviet quantity and composition all across the WPACT were large deviations both in quantity and quality in the acquired equipment. This is especially true for second line/reserve (Category II/III units.)

Many of the Soviet weapons systems never were exported into NSWP countries such the T-64 or T-80 tanks. (T-80s were exported following the end of Cold War, the T-64 became outdated even the most advanced variant using Soviet point of view.) The whole NSWP lagged behind the Soviet Army at least with

5-10 years but in some cases this was rather 10-15 years. Here are only some examples more will be addressed later with more detail:

During the mid '80s first line (first echelon/Category A or Category I with NATO classification) Soviet units already were armed on battalion level with the 9K38 Igla (SA-18) MANPAD or 9K310 Igla-1 (SA-16) while NSPW countries still used almost exclusively only the 9K32 Strela-2 (SA-7) MANPAD. Only a very small quantity of Igla-1 entered into service. For example the acquired ratio between SA-7 and SA-16 was about 10:1 in Hungary.

Before we go further in explanation the strange tank battalion in the mechanized rifle regiment requires more explanation. The peacetime and wartime organization is different. As the army groups are set up only in wartime the yellow marked tank battalion (on the first chart from FM 100-2-3 about motorized rifle regiment) exist only in peacetime

Each mechanized regiment had 3x mechanized battalions and 1x tank battalion in peacetime. In wartime the tank battalions in every mechanized regiments would were dispersed equally for the mechanized battalions. The 30 tanks were assigned to mechanized battalions, 10 tanks to each battalion. Thanks to this change a single mechanized rifle regiment would had only three battalions but each with 40-50APC/IFV + 10 tanks. This would made the unit an "enhanced regiment" resulting a unit much closer in size and firepower to NATO brigade.

In peacetime a mechanized regiment consisted:

1. mechanized battalion (about 40-50 BTR-60/70/80 or BMP-1/2)
2. mechanized battalion (about 40-50 BTR-60/70/80 or BMP-1/2)
3. mechanized battalion (about 40-50 BTR-60/70/80 or BMP-1/2)
1. tank battalion (about 31 T-55/62/72/80)

+ support units

In wartime a mechanized regiment consisted:

1. mechanized battalion (about 40-50 BTR-60/70/80 or BMP-1/2 + 10 tanks)
2. mechanized battalion (about 40-50 BTR-60/70/80 or BMP-1/2 + 10 tanks)
3. mechanized battalion (about 40-50 BTR-60/70/80 or BMP-1/2 + 10 tanks), **reserve battalion**

+ support units

The quantity of battalions and the two acting/attacking and one reserve battalion structure is very important. It defined the way how the air defense was assigned from air defense regiments of the divisions and also the regiment level air defense. Two of three battalions of the regiment would attacked, the another was in reserve in a single mechanized rifle regiment. The tank regiment of the mechanized division also was a reserve unit it could be sent where the attack was successful.[7]

In the attachments are two Excel files[8]. One of them shows the evolution of the homeland and also the army air defense systems. The second one shows the acquisitions of both kind of air defense equipment of

[7] *The doctrine of WPACT and USSR were different comparing to NATO countries. Reinforcement and additional units would were sent where the attack was successful or seemed more promising.*

[8] *SAM Evolution, WPACT-air-defense-acquisitions Excel files*

NSWP countries. They help to understand the quality and quantity difference of armed forces of NSWP countries comparing to the Soviet Union.

Below are listed each level (layer) of air defense without couniting the cumulative missile and equipment quantities on each level. This calculation and analysis can be found later in this chapter.

Of course for SAM systems are composed not only by radars, launcher and missiles but in this chapter only these are accounted for judging the quality and quantity of the air defense. The much more detailed description of the air defense system are in other chapters of this document. Also can be found information concerning on equipment and personnel in FM 100-2-3 and FM 100-60.

The FM 100-2-3 and 100-60 are not 100% accurate but they are good base. The information and data were provided of these documents is corrected and supplemented by the lectors and other sources.

Because in different era different type of equipment were used the explanation below lists every types of weapon systems from different era. Depending of the year it can be determined what was typical for a specific country. The used equipment were the following:

Battalion

The direct air defense of each mechanized rifle infantry battalion is one MANPAD platoon equipped with 9K32 Strlea-2 (SA-7) or 9K34 Strela-3 (SA-14)[9] or 9K310 Igla-1 (SA-16). or 9K38 Igla (SA-18).[10] Each platoon has four squads, each squad has two launchers + one additional commander launcher. In total this means a battalion has 9 launchers.[11]

Regiment

Each mechanized rifle infantry or tank regiment has one battery each battery with two platoons.

- First platoon[12] is equipped with short range missile units. The platoon has four 9K31 Strlea-1 (SA-9) or 9K35 Strela-10 (SA-13) vehicles + 1 command vehicle the BTR-60 PU-12 which provides the target data supply from higher level target acquisition radars (as part of IADS).
- Second platoon is anti-aircraft gun (AAA) platoon. The platoon has four ZSU-23-4 Shilka self-propelled air defense guns + 1 command vehicle the BTR-60 PU-12.
- Regiment headquarters, the HQ has three MANPAD launchers. 9K32 Strlea-2 (SA-7) or 9K34 Strela-3 or 9K310 Igla-1 (SA-16). or 9K38 Igla (SA-18)

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9 *Mainly 3rd world countries fielded and the Soviet Union. Hungary, Poland, Czechoslovakia and East Germany decided to skip it in favor of the all aspect 9K310 Igla-1 (SA-16).*

10 *Nowadays this can be Igla-S (SA-24) or 9K333 Verba (SA-25) these are post-Cold War developed MANPADs in Russia.*

11 *According to FM 100-2-3 the tank battalions did not have direct air defense. According to my lectors this is not exactly true in general. In Hungarian People's Army the MANPAD platoons followed the tank battalion on jeeps or trucks. Maybe they are confused with the air defense of the regiment headquarters (FM 100-2-3 page 43.). They has three MANPAD launchers.*
Also can be the cause of confusion that the tank battalions itself may not have MANPAD defense but in wartime they are dispersed among the mechanized rifle battalions. It means they would enjoyed the defense of MANPADs thanks to the mech. rifle battalion regardless in the peacetime structure they are not part the mechanized rifle battalion.

12 *Regardless this is called platoon as MANPAD platoon it is higher level in the organization because we are talking vehicles not about manpower.*

From 1990 the 2K22M Tunguska (SA-19) platoon started to replace both the missile and AAA platoons. The 1+1 platoon with 4+4 vehicles was replaced with 6x Tunguska[13]. Because of the collapse of the Soviet Union the replacement process was very long it took more than two decades to replace the majority of older units.

Division

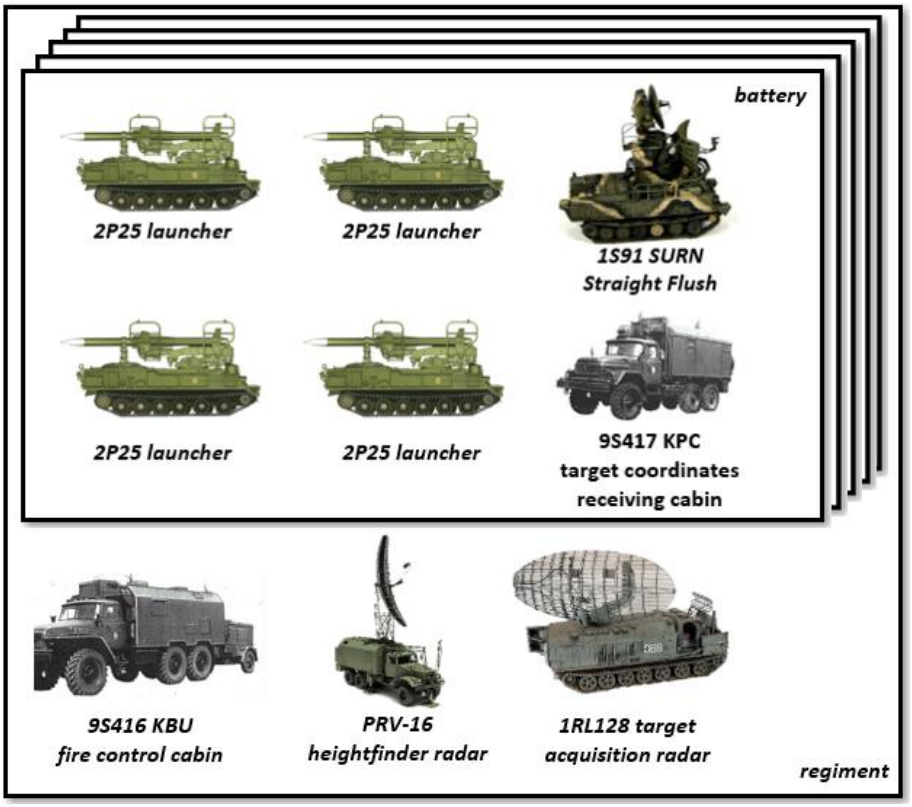
Each division has one air defense regiment. Depending on the country, year and the type of the division the regiment can be 2K12 Kub (SA-6) or 9K33 Osa (SA-8).

- The air defense of a tank division is ensured by one 2K12 Kub (SA-6) regiment. The regiment consists five missile batteries. Each battery has one 1S91 SURN fire control radar (single target channel), four missile launcher (TEL) on three missiles on each TEL (+other utility vehicles such as reloaders, Missile Preparation/Assembly Station, etc.). A single battery has a single target channel and 12 missiles on launch vehicles. The regiment in total has five target channels and 5x(4x3) = 60 missiles ready to launch.

  The regiment also has command battery with a P-40 long range radar target acquisition and IADS elements both in the command and missile batter. See in the description of the 2K12 Kub in its chapter.

  Each missile battery has for self-defense three MANPAD launchers, three MANPAD launchers. 9K32 Strlea-2 (SA-7) or 9K34 Strela-3 or 9K310 Igla-1 (SA-16). or 9K38 Igla (SA-18).

  The missile technical battery is also equipped with for self-defense three MANPAD launchers any type from listed previously for air defense platoons of the battalions.



[13] *FM 100-2-3 mention only four which is inaccurate as I can judge. FM 100-2-3 was made before the replacement process happened on larger scale.*

- The air defense of a mechanized rifle division is ensured by one 9K33 Osa (SA-8) regiment. The regiment has five batteries each with four vehicles. Each vehicles has one target channel and six missiles (AK and AKM variants have six only the small quantity initial variant had four missiles). In total the regiment has 20x target channels and 120x missiles ready to launch.

- The division headquarters, the HQ has six MANPAD launchers. 9K32 Strlea-2 (SA-7) or 9K34 Strela-3 or 9K310 Igla-1 (SA-16). or 9K38 Igla (SA-18).

The replacement system both of the 2K12 and 9K33 SAMs is the 9K331 Tor-M1 (SA-15) which is a post-Cold War system similarly to the 2K22M Tunguska. The replacement process started in early '90s. Their development started way back in the Cold War but their introduction was strongly delayed by financial issues and difficulties in development.

The development of the Osa was delayed by almost a decade comparing to initial fielding date goal. Therefore the mechanized rifle divisions of the NSWP got 2K12 Kub regiments instead the planned 9K33 Osa. This meant a big financial burden on their national economies regardless the Kub had much less target channel in exchange for larger engagement range. (See the engagement range at the description of 2K12 Kub system.) Some NSWP countries bought later the 9K33 Osa and replaced the 2K12 Kub which were assigned to their original planned units. But not every NSWP countries followed this way. For example Hungary never bought not a single Osa vehicle.

As I can judge because of the experience of Cold War conflicts was replaced the 2K12 Kub with 9K331 Tor-M1. It was higher priority to provide more missiles ready to launch with more target channels per vehicle. The larger range of the Kub did not provide real benefits in the '80s. Against tactical fighters the 6 km maximal altitude and 11-12 km range of the Tor-M1 was more than enough.

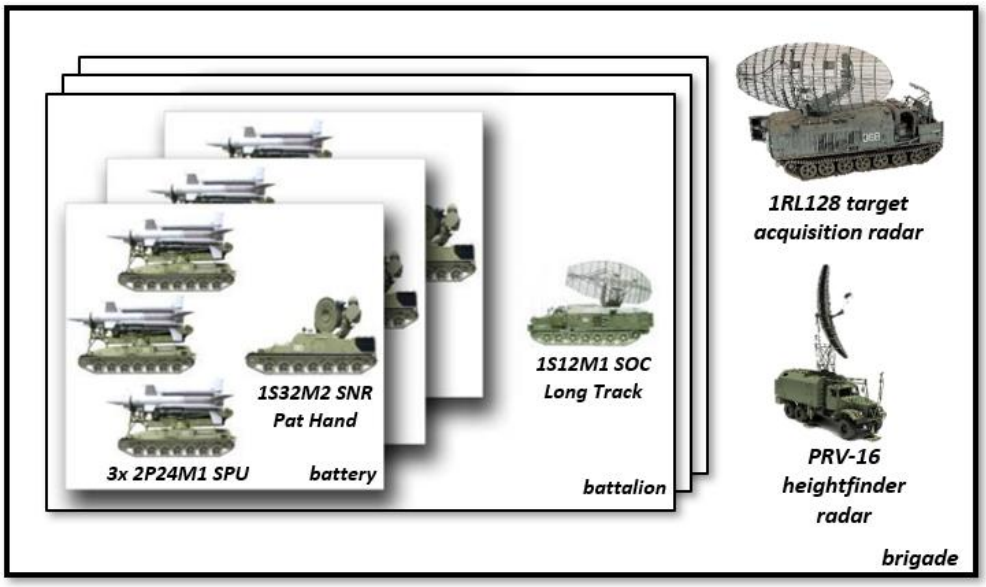
In the '80s the most advanced widely used air to ground missiles on airplanes was the AGM-65. Because of the limitation of the EO/IR or laser seeker and other issues regardless of the kinematic range of the missile the useful launch range was way below 10 km at 3-4 km launch altitude or even lower. In case less advanced strike airplanes with only dumb bombs and unguided rockets the attackers had to fly even more closer to their targets way within the range of the Osa AK/AKM.

Considering these factors the engagement range of the Osa was sufficient. The problem was even Osa AK and AKM carried only six missiles and not eight which was requested and had only a single target channel.

The amphibious capability request was cancelled but in exchange it was possible to use a much heavier chassis which made possible to carry more missile and more and heavier electronics. The more advanced hardware made possible for the Tor-M1 to have two target and four missile channels. The Tor-M1 can defend itself against ARMs and it does not have to turn off in case of SEAD activity.

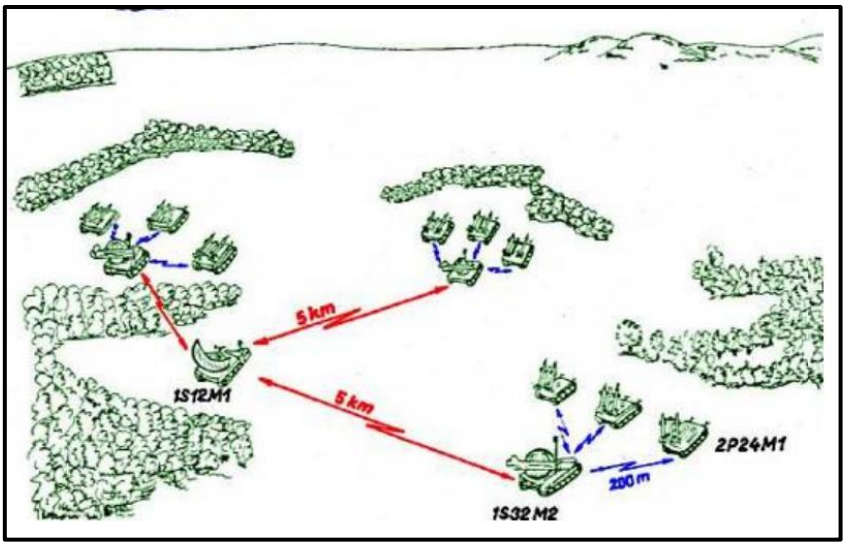
Army

Each army has one 2K11 Krug (SA-4) air defense brigade. The replacement type of the Krug is the 9K37 Buk-M1 (SA-11) first appeared at in 1987.



A 2K11 Krug brigade consists three firing battalions.[14] Each battalion has three batteries, each battery has three launchers with two missiles on each. In total a brigade has 9x batteries and 27x launchers and 54x missiles ready to launch. On the diagram above is a 2K12M1 Krug battalion.

Each battery has its own 1S32 SNR (Pat Hand) fire control radar with a single target and missile channel. The 1S12 SOC (Long Track radar) feeds with target coordinates via data link the batteries. Comparing to Kub system all IADS equipment is integrated into the 1S12 and 1S32 vehicles there is no need any additional IADS vehicle. Besides all of previously listed radars the brigade has a P-40 system with is consisted by the 1RL128 target acquistion radar and PRV-16 heightfinder radar similar to the 2K12 Kub regiment.



Typical deployment of a single 2K11 Krug firing battalion with 3x firing batteries.

[14] http://sites.google.com/site/samsimulator1972/home
From the manual of the SA-4 simulator.

It is very important to understand the difference between the P-40 complex and the 1S12 SOC Long Track radar. Sadly almost every pictures, sources or drawings are inaccurate about these systems. There is a total confusion about their designations, names or just the images which are attached to their description.

The P-40 as a complex in reality means the 1RL128 target acquisition radar and the PRV-16 heightfinder radar together.[15]

Above left is the 1S12 Long Track radar above right is the 1RL128 radar. The marked diamond shaped "net" part is a very well visible feature of the antenna of the 1S12 Long Track which is missing on the 1RL128.

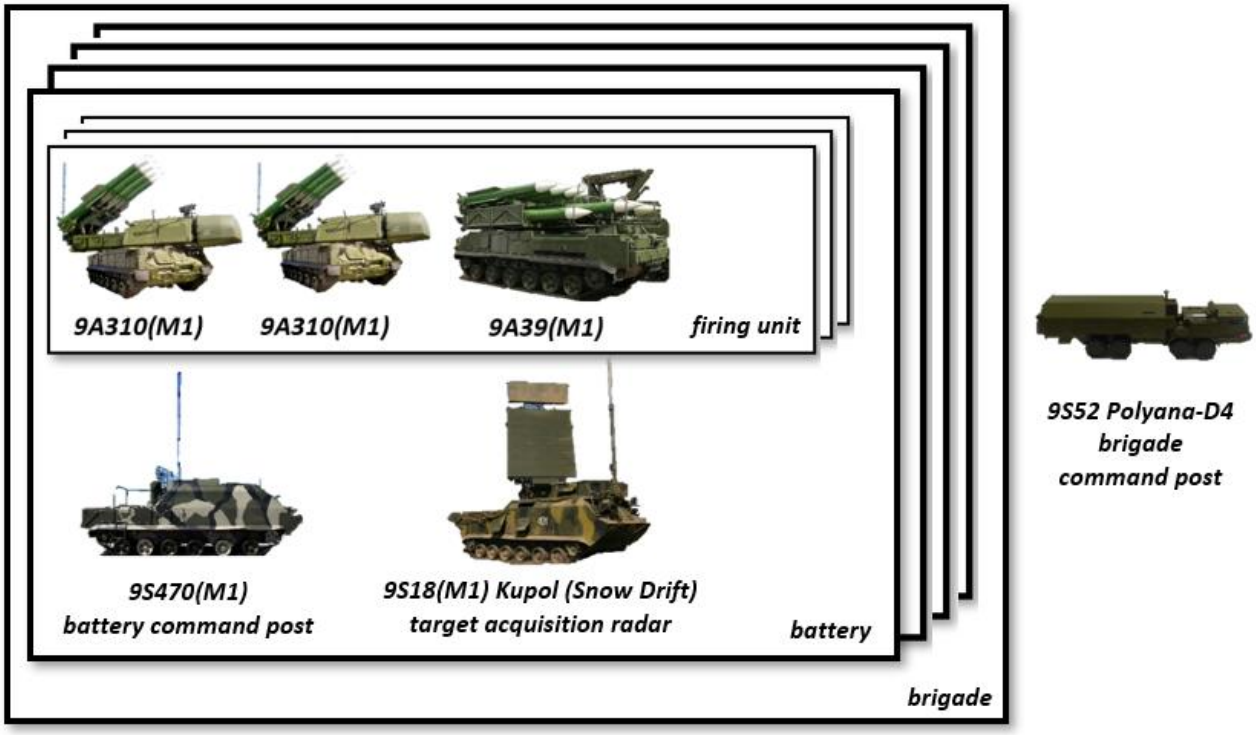
The 1RL128 radar vehicle supplies with power the towed PRV-16 radar. These are part of the command post of the Krug brigade which acts also as the air defense command post of an army. This is the location in the structure and organization where is decided which tool is used for dealing with targets, land based air defense unit or fighters.

For ground controlled fighter interception is needed the PRV radar to provide accurate altitude data. For the Krug firing batteries this data is not so crucial. In case Krug is selected the P-40 complex forwards the data to the appropriate 1S12 SOC (Long Track) which assign a Krug 1S32 SNR (Pat Hand) which using only azimuth coordinates with quick elevation scan finds its target.

The P-40 is the result of the experience of the Cold War conflicts for the 2K12 (SA-6). The base idea was Kub batteries use the 1S91 SURN for target acquisition and fire control with 1S31 and 1S11 antenna systems. (See in the chapter about the 2K12 Kub.) In the Arab-Israeli wars became evident it was not a good idea to use continuously for target acquisition the 1S91 SURN. Because of this experience got the 2K12 Kub regiment later the P-40 + 9S416 and 9S417 vehicles which were originally were not designed to the system. These made possible to get target coordinates from higher level radar without using and revealing the positions of the batteries.

The P-40 complex was exported outside the Warsaw Pact countries but the 1S12SOC was not because it was part of the 2K11 Krug system. The 2K11 was used by exclusively the Warsaw Pact.

[15] https://www.valka.cz/SOV-P-40-1RL111-1RL128-1S12-Long-Track-t29368



From late '80s started replacing the 2K11 Krug with 9K37M Buk-M1 (SA-11) but only a very few (full brigade) units were fielded until the end of Cold War. Initially a part of Buk brigade could be integrated to 2K12 Kub batteries (SA-6) as additional TEL and fire channel. This was only an early conception the idea later was cancelled.

A full 9K37 Buk-M1 brigade consists four batteries, each battery has three firing units.

Each firing unit has two 9A310(M1) TELARs[16] which is able to provide target illumination for the SARH guided missiles and one 9A39(M1) TEL. The TELAR has one target channel[17] and four missiles, the TEL has eight missiles.

Each battery has one 9S18(M1) Kupol (Snow Drift) target acquisition radar, one 9S470(M1) battery command post vehicle the and three firing units.

The brigade has one command post vehicle the 9S52 Polyana-D4. The Polyana-D4 brigade command post is not displayed inside the Buk-M1 brigade on diagram because it is not only the brigade command post exclusively of the Buk-M1 brigade but also serves as an IADS element between the S-300V brigade. Moreover the Polyana-D4 is able to establish data link with A-50 AWACS airplanes.

In fact the Polyana-D4 is rather an army group level command post than just an air defense brigade command post. It is roughly equivalent with the VS-1 Vozduh homeland air defense system but it is fully mobile.

The available missiles on rails and target channels for a Buk-M1 systems are the followings:

16 *TELAR = transporter erector launcher and radar, TEL = transporter erector launcher*

17 *The whole section concerning about the Buk-M1 variant, the M2 and M3 variants have more target channels. See the exact values in later chapter in the description of the Buk SAM family. The M1 variant was selected because the point of the analysis to see the impact of the Krug --> Buk-M1 replacement.*

A single firing unit has:

- 2x target channels (because of the two TELAR)
- 16x missiles ready to launch (2x4 + 8)

A single battery has:

- 6x target channels (3x2)
- 48x missiles ready to launch (16x3)

A brigade has:

- 24x target channels (4x3x2)
- 192x missiles ready to launch (4x16x3)

The deployment method of a Buk-M1 brigade likely similar to the 2K11 Krug brigade. The batteries would deploy from each other to larger distances (15-25 km) while the firing batteries group around the 9S18 Kupol (Snow Drift) target acquisition radar and 9S470 battery command post about up to 5 km distance.

Comparing to Krug (SA-4) Buk-M1 was a big step ahead both in quantity of missiles ready to launch and target channels. While a total Krug brigade had 9x target channels the Buk has 24x, almost three times much. Comparing to the 54x missiles on launchers the Buk-M1 has 192x which is more than three times much. Checking the maximal engagement at first sight it seems that Krug has range advantage with 45 km over only 35 km of the Buk-M1. But **considering the typical altitude of tactical fighters** (less than 10 km) the engagement range of the Buk-M1 and best Krug variant are the same. In practice the covered area comparing to Krug is much higher because of more batteries. During relocation the firepower reduction is also smaller because the Buk-M1 battery looses only 1/4th of the available in case one battery moves while the Krug lost 1/3rd.

In theory the 2K11 Krug had ABM capability up to 800 m/s target speed (with a very small engagement zone) which was lacked the BukM-1 (on paper). Buk-M1 does not have ABM capability it is available from Buk-M1-2 variant. Considering the 1200 m/s max target speed of the S-300V for “normal firing units” the missing ABM capability of the Buk-M1 brigade is not a big deal the ABM role simply was given to S-300V. Only problem only a very few S-300V were manufactured until the end of the Cold War only two brigades. Regardless officially Buk-M1 does not have ABM capability Finnish crew at fire range qualification trials for the first attempt downed an 800 m/s fast target.

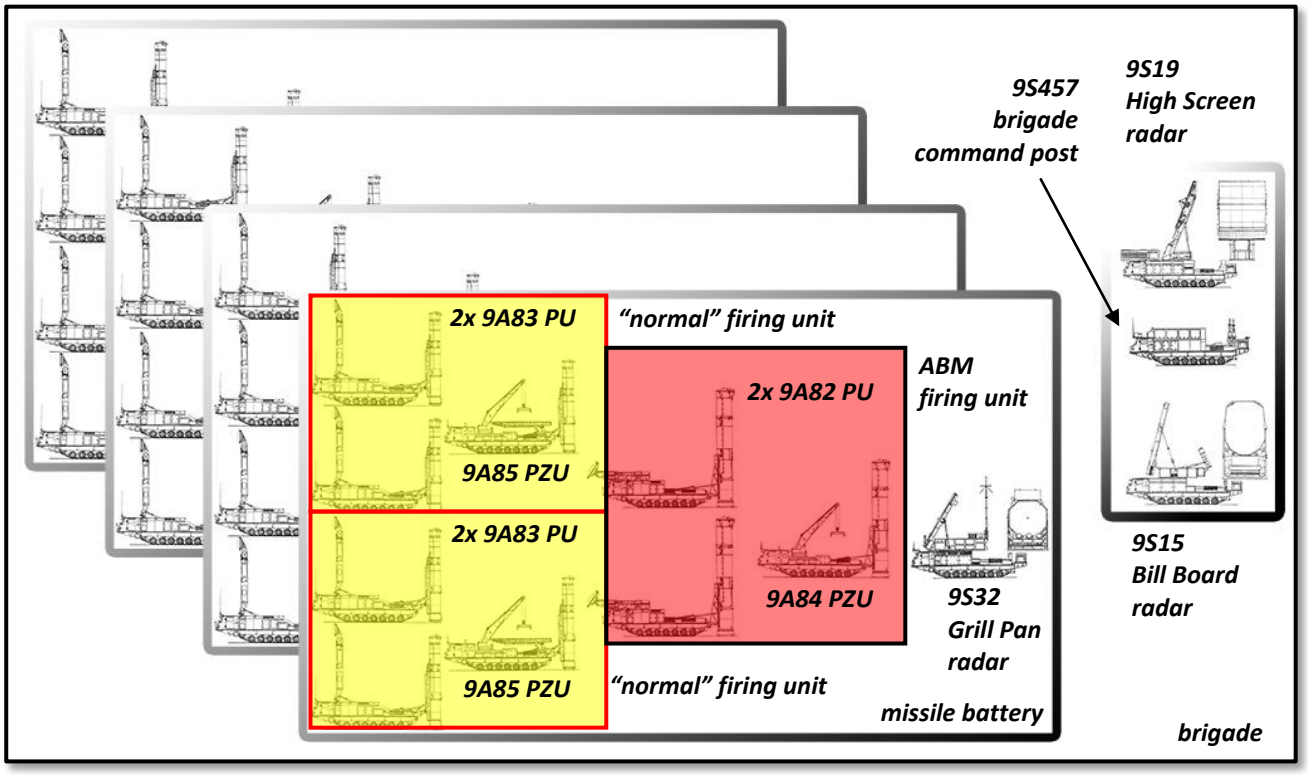
We can say losing the minimal ABM capability of the Krug following the introduction on Buk-M1 was not a big deal. The Buk-M1 outclassed the older Krug in every area except the “analog LPI” capability. See in the more detailed description of the Krug later.

Army group

Each army group has one 2K11 Krug (SA-4) air defense brigade which is identical what has been explained above for army.

The replacement type of the Krug is the 9K81 S-300V (SA-12B) which first appeared at in 1988. The early limited capability variant the S-300V1 (SA-12A) appeared first in 1983. The V1 variant lacked the ABM capability against the Pershing II ballistic missile. Until 1990 only two brigades were manufactured. Only in East Germany was replaced the S-300V the older Krug.

Not every NSWP countries had its own army group level SAM defense. For the army group in Czechoslovakia the Czech Army ensured the army group level air defense while in Hungary the Soviet Union provided the Krug brigade for this purpose.



One S-300V brigade with 4x batteries, each battery with two "normal" and one ABM firing units.

An S-300V (SA-12B) brigade consists four firing batteries and one command battery.

The command battery has the following main equipment:

- 9S15 Bill Board long range target acquisition radar
- 9S19 High Screen long range ballistic missile search radar
- 9S475 brigade command post

The missile battery has two normal and one (except V1 variant) ABM firing unit and the 9S32 Grill Pan central firing control radar. The normal firing units are used against airplanes, anti-radiation missiles, cruise missiles and slower (<M3.0) ballistic missile while the AMB firing unit is reserved against Pershing II or other fast and advanced ballistic missiles such as ATACMS or any similar kind of threat.

- Each normal firing unit has two 9A83PU TELAR vehicles with one target channel and four missiles on each. Besides that it has one 9A85PZU TEL/loader also with four missiles. The 9M83 type missile is used in normal firing battery.

- Each ABM firing unit has two 9A82 PU TELAR vehicles with one target channel and two missiles or each. Besides that it has 9A84 PZU TEL/loader also with two missiles. The 9M82 type missile is used in normal firing battery.

Both the 9A83 and 9A82 TELAR has one target channel. The TELARs illuminates the target with CW radar in terminal phase. Until that point the 9S32 Grill Pan radar and its equipment guide the missiles. In total 6x missiles can be guided in the same time with radio command guidance (6x target channel). Of course the ABM missiles also can be used against aircraft moreover, one of its special mode was against stand of jammer airplanes such as EF-111A. The 9M82 missile has larger kinematic range than 9M83.

In total in a single missile battery has:

- 6x 9M82 ABM missiles with 2x ABM target channels by 9A82
- 24x 9M83 missiles against “slow” targets with 4x target channels by 9A83

The full S-300V brigade had 4x firing batteries, in total:

- 24x 9M82 ABM missiles with 8x ABM target channels 9A82
- 96x 9M83 missiles against „slow” targets with 16x target channels 9A83

The S-300V1 was different from S-300V it did not had the ABM capability against Pershing II because High Screen radar and the ABM firing units were not available. First S-300V1 entered in service in 1983. The max. target speed of the “normal” firing units was 1200 m/s therefore even without the new ABM capability could be used against same ballistic missiles as the Krug with better kill probability.

As the S-300V system become ready for fielding only at the end of the Cold War it was actually fielded in really limited numbers. Even today in Google Earth only less than a half dozen S-300V brigades can be identified. [18]

- Kaliningrad, Gvardeysk
- Ukraine, Uman
- Armenia, Gyumri
- Moscow, Naro-Fominsk
- Far East, Tavrichanka

Before the arrival of the 2K11 Krug the S-75M Volkhov (SA-2E) was used as army and army group level air defense. In the Soviet Union the Krug replaced the Volhkov. In NSWP countries before acquiring of the 2K11 Krug the 2K12 Kub (SA-6) was used as interim solution. Before these missile air defense did not exist.

[18] http://simhq.com/forum/ubbthreads.php/topics/4159194/S-300V/VM_(SA-12/23_Giant_-_Gl

If we look and compare well the AEGIS system and the S-300V we can see how similar they are. The main difference that AEGIS is installed on large destroyers or missile cruisers. Because of the platform it has 360 engagement degree capability if we consider the ships as single missile battery. In terminal phase for not active radar guided missile the AEGIS also uses independent CW illuminators just as the S-300V.

If the S-300V had four Grill Pan radar it would have 360 degree engagement zone. Because of the NATO vs WPACT geography the 360 degree engagement zone was pointless. The designers could be sure about the main threat direction of missiles. Of course the Grill Pan can be turned any direction but its azimuth scan limit restricts the engagement zone in a given engagement situation. While the AEGIS system in the same time can engage targets in 360 degree zone. We can say S-300V is a land based mobile, partially downscaled AEGIS. See later the description of the AEGIS system is the Naval Air Defense Chapter.

For understanding the quality and quantity of the air defense in different ears it has to be consider the rate of replacement of older equipment. In the Soviet Union generally the first initial variant is produced slowly and only in a very limited quantity. Considering the issues in manufacturing process and first experiences in service could come the first really mass produced variant. For example was a four year gap between the S-75 Volkhov and the first really mas produced version the S-75M.

Another good example is the 9K33 Osa family. Following the successful state trials in 4th of October in 1971 was accepted the Osa but only a very few was manufactured from the base variant. Only 1 in 1970, 3 in 1971 and 15 in 1972. In 1973 was set up the first regiment but only with 12 Osa vehicles while the nominal regiment size would be 20. This variant had only 4x missiles in rails while the later upgraded AK and AKM variants was able to carry 6x in canisters (containers). Regardless of these values on Wikipedia page of the Osa we can see as initial operational capability (IOC) the year of 1971. Regardless this date even in the Soviet Army was not prevalent until the late ’70 and early ’80 at the first line units.

The first 2K22 Tunguska existed in mid ‘80s but the replacement with 2K22M started only from 1989/90 and only a very few regiments got it. The first trials of the 9K330 Tor were conducted in around 1984 while the 9K331 Tor-M1 production and fielding started only in 1991. Regardless both the Tunguska-M and the Tor-M1 were developed during the Cold War their real IOC and wide spread usage happened after the Cold War. Even today (2019) they have not been fully replaced their predecessors.

The charts below summarize all the information what were explained above with the following condition:

- The Chart 1. summarizes the structure and inventory of a mechanized infantry division in mid-late ‘80s.
- The Chart 2. summarizes the structure and inventory of a tank division in mid-late ‘80s.
- The Chart 3 summarizes the structure and inventory of an army and army group in mid-late ‘80s considering five divisions in an army **without the reserve division**.
- In Charts 1 and 2 below are showed the equipment before the arrival of the new “double digit” radar guided SAMs such as 2K22M Tunguska and the 9K331 Tor-M1. Notes are added about the plan for replacement. They are not additive equipment for the regiments and divisions. Same case the S-300V and Buk-M1 replacement in Chart 3.
- For easier understanding is mostly **used only the designation of the family without additional denomination**. For example 2K12 Kub can mean any variant of them. The important is the main type of the system. The Tor-M1 and Buk-M1 are labelled exactly to avoid the confusion with later, much more advanced variants of them.

Mechanized division in WPACT (Soviet) Chart 1				
battalions		*regiments*		*division*
1.	***tank battalion***	***1.***	***tank regiment*** *same air defense what mechanized rifle regiment has*	***mechanized rifle division**** 3x mech. rifle regiments 1x tank regiment *air defense regiment provides the <u>division level air defense</u> 9K33 Osa AKM (SA-8) regiment with* • *5x SA-8 batteries in total with* • *20x target channels (5x4)* *120x missiles (5x4x6)* *<u>each battery with:</u>* • *1x command vehicle* • *4x 9A33 TELAR vehicles* *6x missiles/TELAR* • *2x 9T217BM2 TZM missile carriers/loaders* *12x missiles/vehicle* *+ division HQ with 6x MANPAD launchers** *The plan was replace with 9K331 Tor-M1 (SA-15) regiment* • *5x Tor-M1 batteries* • *1x command battery* *40x fire channels (5x4x2)* *160x missiles (5x4x8)* *<u>each battery with:</u>* • *1x 9S737 command. vehicle* • *4x 9A331 TELAR vehicles* *8x missiles/vehicle* • *2x 9T244 missile carrier/loader*
2.				
3.				
4.	***mechanized rifle battalion nominally 40-50 + 2 cmd. APC/IFV*** *1x Strela-2/3 or Igla-1/Igla air defense platoon, each platoon with 4x squads, each squads with 2x MANPAD launchers/squad + 1 cmd. launcher = total 9x launchers/battalion.**		***mechanized rifle regiment (BTR)*** *1xbattery with 2x platoons* • *1x ZSU-23-4 Shilka platoon, each platoon 4x ZSU-23-4 vehicles.* • *1x Strela-1/10 platoon, each platoon with 4x vehicles*** *+ regiment HQ with 3x MANPAD launchers, depending on era Strela-2/3 (SA-7/14) or Igla-1 (SA-16) or Igla (SA-18) during Cold War* *The plan was replace 4+4 Shilka + Strela-10 with 6x 2K22M Tunguska.*	
5.	***mechanized rifle battalion***			
6.	***mechanized rifle battalion***			
7.	***tank battalion – nominally 30 + 1 cmd. tank*** *It does not have MANPAD defense according to FM 100-2-3 but according to other sources it may have.*			
8.	***mechanized rifle battalion***	***3.***	***mechanized rifle regiment (BTR)***	
9.	***mechanized rifle battalion***			
10.	***mechanized rifle battalion***			
11.	***tank battalion***			
12.	***mechanized rifle battalion***	***4.***	***mechanized rifle regiment (BMP)***	
13.	***mechanized rifle battalion***			
14.	***mechanized rifle battalion***			
15.	***tank battalion***			
	<u>Support units per battalion:</u> *mortar battery, supply platoon, signal platoon, etc.,* *In fact the air defense platoon (MANPAD) should be here, but I put them upper cells to make more easily countable the air defense.*		***<u>Support units per regiment:</u>*** *recon company, engineer company, chemical protection platoon, howitzer battalion, etc.* *In fact the air defense battery should be here, but I put them upper cells to make more easily countable the air defense*	***<u>Support units per division:</u>*** *recon battalion, ballistic missile battalion (SSM), artillery regiment etc.* *In fact the air defense regiment should be here, but I put them upper cells to make more easily countable the air defense*

*	*3x missile supply for each launcher. In 1990 Soviet Union already phased out Strela-2, and Strela-3 mostly (?) was replaced with Igla-1 (SA-16) or Igla (SA-18)*
**	*In 1990 the Soviet Union already phased out the Strela-1 only some NSWP countries used.*
***	*Because of delayed development and production of 9K33 Osa SAM system (SA-8) many NSWP countries bought the 2K12 Kub (SA-6) air defense regiments for mechanized divisions instead Osa regiments. Some of them later bought also the Osa then SA-6 was forwarded to tank/armored divisions. Hungary never bought Osa. This is why in FM 100-2-3 mentioned the divisional level SAM protection as "sometimes Osa sometimes Kub".*

Tank division in WPACT (Soviet) *Chart 2*				
battalions		*regiments*		*division*
1.	***tank battalion***	***1.***	***tank regiment*** *same air defense what mechanized. rifle regiment has*	***tank/armored division*** 3x tank regiments 1x mech. rifle regiment *air defense regiment provides the <u>division level air defense</u>* *2K12 Kub (SA-6) regiment with* • *5x Kub batteries in total with* *5x target channels* *60x missiles (5x4x3) on TELs* *<u>each battery with:</u>* • *1x SURN fire control and search radar (Straight Flush) provided* *1x target channel* *1 x target channel, up to 3 missiles for a single target* • *4x launchers (TELs)* *3x missiles / TEL* *(+ reload)* *+ division HQ with 6xMANPAD launchers** *The plan was replace with 9K331 Tor-M1 (SA-15) regiment* • *5x Tor-M1 batteries* • *1x command battery* *40x fire channels (5x4x2)* *160x missiles (5x4x8)* *<u>each battery with:</u>* • *1x 9S737 command vehicle* • *4x 9A331 TELAR vehicles* *8x missiles/vehicle* • *2x 9T244 missile carrier/loader*
2.	***tank battalion***			
3.	***tank battalion***			
4.	***tank battalion***	***2.***	***tank regiment***	
5.	***tank battalion***			
6.	***tank battalion***			
7.	***tank battalion***	***3.***	***tank regiment***	
8.	***tank battalion***			
9.	***tank battalion***			
10.	***mechanized rifle battalion – nominally 40-50 + 2 cmd. APC/IFV*** *1x Strela-2/3 or Igla-1/Igla air defense platoon, each platoon with 4x squads, each squads with 2x MANPAD launchers/squad + 1 cmd. launcher = total 9x launchers/battalion.**	***4.***	***mechanized rifle regiment (BMP)*** *1xbattery with 2x platoons* • *1x ZSU-23-4 Shilka platoon, each platoon 4x ZSU-23 vehicles.* • *1x Strela-1/10 platoon, each platoon with 4x vehicles.*** *+ regiment HQ with 3x MANPAD launchers, depending on era Strela-2/3 (SA-7/14) or Igla-1 (SA-16) or Igla (SA-18) during Cold War* *The plan was replace 4+4 Shilka + Strela-10 with 6x 2K22M Tunguska.*	
11.	***mechanized rifle battalion***			
12.	***mechanized rifle battalion***			
13.	***tank battalion – nominally 30 + 1 cmd. tank*** *It does not have MANPAD defense according to FM 100-2-3 but according to other sources it may have.*			
	<u>Support units per battalion:</u> *mortar battery, supply platoon, signal platoon, etc.,* *In fact the air defense platoon (MANPAD) should be here, but I put them upper cells to make more easily countable the air defense.*		***<u>Support units per regiment:</u>*** *recon company, engineer company, chemical protection platoon, howitzer battalion, etc.* *In fact the air defense battery should be here, but I put them upper cells to make more easily countable the air defense*	***<u>Support units per division:</u>*** *recon battalion, ballistic missile battalion (SSM), artillery regiment etc.* *In fact the air defense regiment should be here, but I put them upper cells to make more easily countable the air defense*

ARMY GROUP (FRONT)
Chart 3

<table>
<tr><th>Divisions</th><th>Army</th><th>Divisions</th><th>Army</th><th rowspan="2"></th></tr>
<tr>
<td>mechanized rifle division</td>
<td rowspan="4">tank / armored army
2-4x armored divisions, (here is 3x)
0-2x mot. rifle divisions, (here is 2x)

air defense regiment provides the
<u>army level air defense</u>:
2K11 Krug (SA-4) brigade with:
• 3x Krug battalions in total:
9x (3x3) target channels
54x missiles on TELs (3x3x6)
(+ reload)
P40 = 1RL128+ PRV-16 radar for the brigade

<u>for each firing battalion</u>:
• 3x firing batteries
• 1x 1S12 Long Track target acquisition radar

<u>for each firing battery</u>:
• 1x 1S32 Pat Hand fire control radar
1x target channel
• 3x launchers / TELs
2x missiles / TEL</td>
<td>mechanized rifle division</td>
<td rowspan="4">mechanized rifle army
4x mot. rifle divisions
1x armored divisions,

air defense regiment provides the
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1x target channel
• 3x launchers / TELs
2x missiles / TEL</td>
<td rowspan="4">Depending on goal, location and era 2-3 armies (here is 2x) would consisted an army group. Depending on date and goal can be huge difference what an army can has because rearming with new stuff never happened in the same time for the whole army, not even for divisions. Also was a factor that armies always were built up by Soviet + NSWP forces which were much weaker comparing to level of USSR considering qty. and quality either.

The army group covered about 200-250 km wide frontline, one army about 100 km.

The army group air defense was provided by the same 2K11 Krug brigade as for an army until late ‘80s. Until 1990 only about two S-300V brigades were manufactured one was located in East-Germany.

The plan was replace the Krug brigade with S-300V (SA-12B) brigade which consists:

• 1x command battery with 9S19 High Screen + 9S15 Bill Board radars and 9S457 command post
• 4x firing batteries in total with
24x target channels (16+8 ABM)
120x missiles (96+24 ABM)

<u>each firing battery with:</u>
• 2x “normal” firing units
• 1x ABM firing unit
• 1x Grill Pan fire control radar

<u>each ABM firing unit with</u>
• 2x 9A82 PU launchers, 2x2 missiles
• 1x 9A84 PZU launcher/loader, 1x2 missiles

<u>each normal firing unit with</u>
• 2x 9A83 PU launchers, 2x4 missiles
• 1x 9A85 PZU launcher/loader,1x4 missiles</td>
</tr>
<tr>
<td>mechanized rifle division</td>
<td>mechanized rifle division</td>
</tr>
<tr>
<td>tank division</td>
<td>mechanized rifle division</td>
</tr>
<tr>
<td>tank division</td>
<td>The plan was replace the 2K11 Krug with 9K37 Buk-M1 (SA-11) regiment Only a very few SA-11 brigade was manufactured until 1990.

<u>One Buk brigade consist in total:</u>
• 4x Buk-M1 missile battery
• 1x command battery
24x target channels (4x3x2)
192x missiles on TELs/TELARs (4x3x16)

<u>each battery consists:</u>
• 3x firing units

<u>Each firing unit consists:</u>
• 2x SOU/TELAR vehicles, 4x missiles/TELAR
• 1x PZU/TEL 8x missiles/TEL
(+ reload)</td>
<td>mechanized rifle division</td>
<td>The plan was replace the 2K11 Krug with 9K37 Buk-M1 (SA-11) regiment Only a very few SA-11 brigade was manufactured until 1990.

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• 1x command battery
24x target channels (4x3x2)
192x missiles on TELs/TELARs (4x3x16)

<u>each battery consists:</u>
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• 1x PZU/TEL 8x missiles/TEL
(+ reload)</td>
</tr>
<tr>
<td>tank division</td>
<td>tank division</td>
</tr>
</table>

For understanding the organization and the availability of the air defense some additional notes are needed:

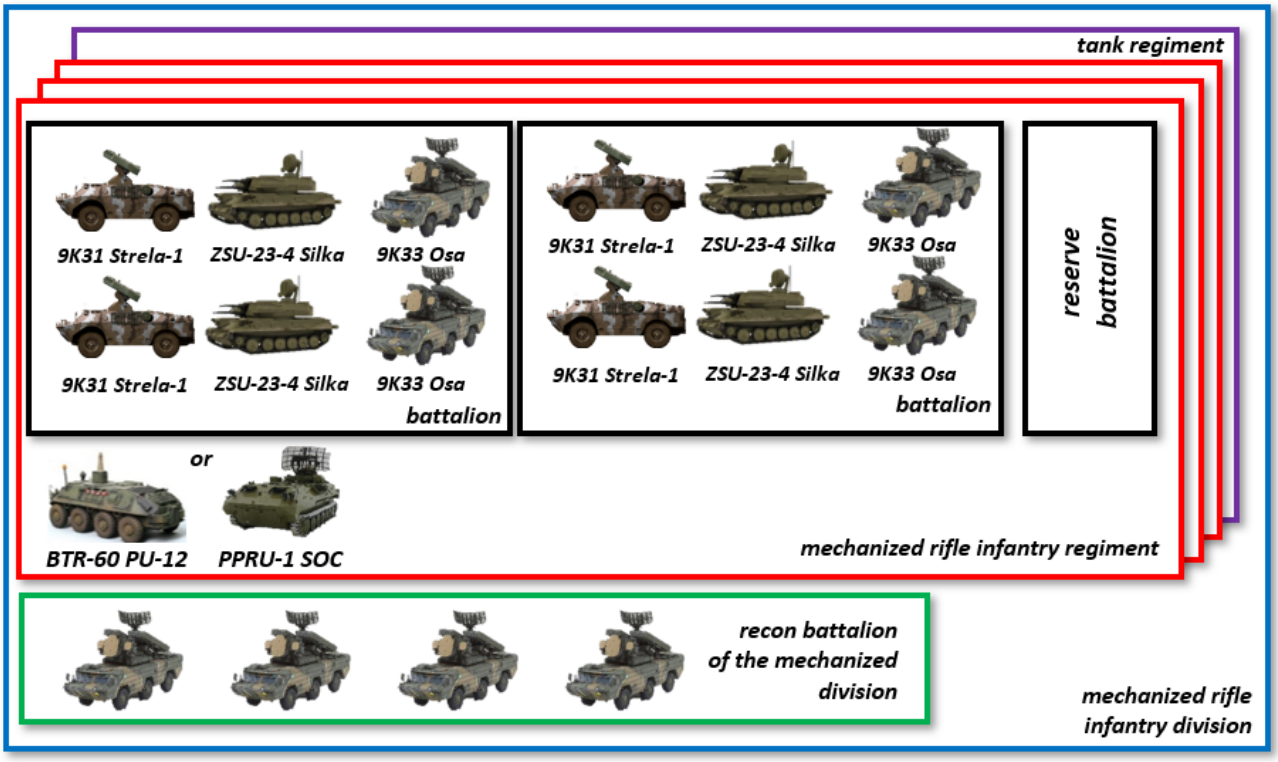
- The nominal 4x Strela-1/10 and the 4x ZSU-23-4 Shilka are available for a single regiment which in wartime consist three battalions. Two battalion would be the attacking unit with a reserve battalion. To each of the two attacking battalion are assigned 2-2 ZSU-23-4 Shilka AAA and a Strela-1/10 SHROAD SAM while the reserve battalion did not have any attached air defense except its MANPADs.

  Following the replacement of the 2K22M 3-3x vehicles are assigned to each attacking battalion.

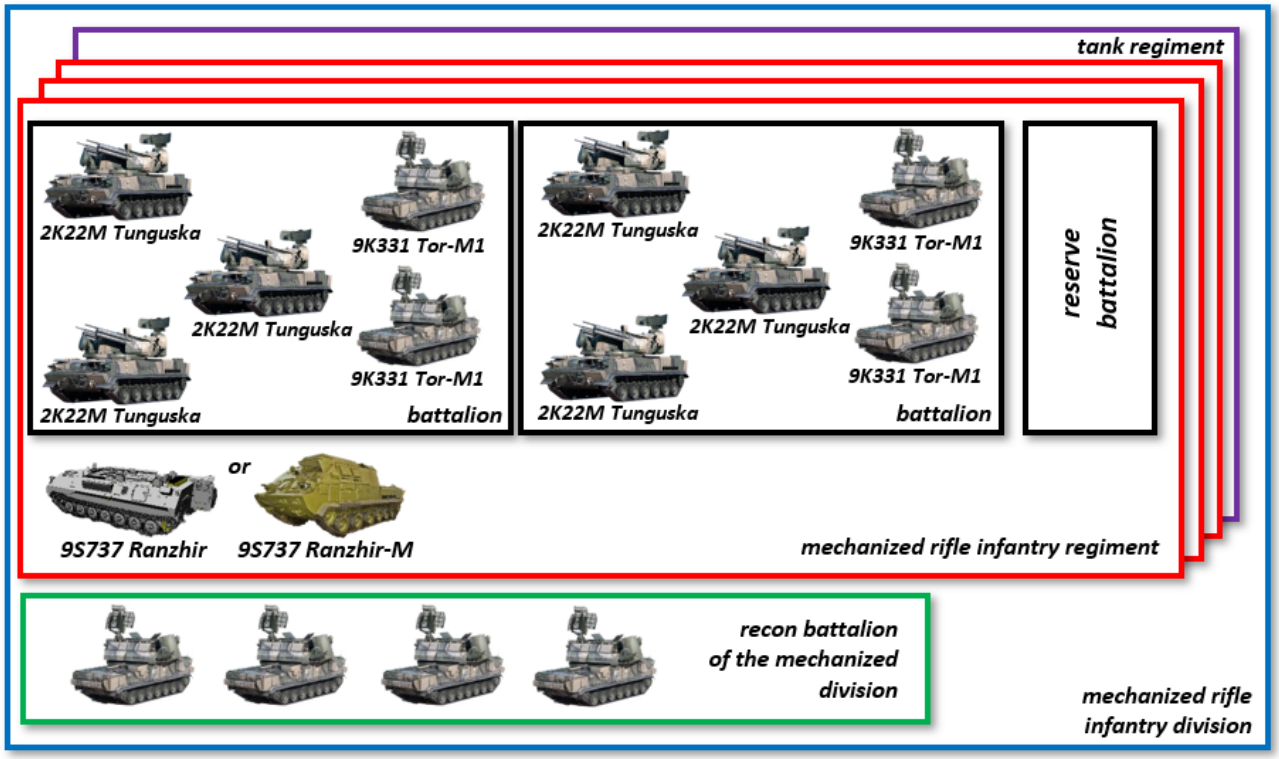
- The case is similar for 9K33 Osa and 9K331 Tor-M1. In total the air defense regiment has 20 vehicles. One pair is assigned to each attacking battalion. This means 4x2=8x battalions with is equal with 16x radar SHORAD vehicles. The remaining 4x Osa/Tor-M1 are assigned to the recon battalion of the division. **The reserve battalions do not get any Osa and Strela1/10 SHORAD vehicle.**

- From the three mechanized rifle regiment in mechanized division two is BTR (wheeled) and one is BMP (tracked) equipped. The mechanized rifle regiment in tank division is BMP equipped.

On the diagram below every information is summarized concerning on mechanized rifle division. Depending on the unit and the era 9K31 Strela-1 (SA-9) was replaced with 9K35 Strela-10 (SA-13). In NSWP and 3rd world countries because lack of funds (or ban on export) the BTR-60PU was available. For the Soviet first line units the PPRU-1 SOC was the command post. The PPRU-1 SOC had its own target acquisition radar while the BTR-60PU relied on higher level radars. See in more detail the IADS equipment in a later chapter.



Following the replacement of the 2K22M Tunguska (SA-19) the quantity of commanded vehicles were changed as well as the command post vehicles. Because of the 9K33 Osa ---> 9K331 Tor-M1 the available target channel quantity is also increased. In end of the Cold War the 9S737 Ranzhir and nowadays the 9S737 Ranzhir-M is available as command post. See in more detail the IADS equipment in a later chapter.



It has to be emphasize the diagrams above the about the distribution of the air defense are the idealized. In reality the air defense can be assigned whatever the commanders decide. For example instead giving air defense to recon battalion is not a fiction to provide better air defense for rear valuable assets such as FROG-7 ballistic missile battalion, artillery regiment or division HQ. In Hungary during a exercise the Soviet leadership reprimanded the Hungarians because they provided too weak air defense for their BM units.

The point of the whole chapter to get an idealized picture about **a possible and generalized distribution** of the target channels and missile. Any other scenarios with the same of different unit composition can be derivable from the idealized case. Different air defense distribution also can be considered.

These factors have impact on the following calculated values and also on the idealized target channel layout.

A note about the structure and organization regarding armored personal carriers (APC) and infantry fighting vehicles (IFV). Because of the CFE treaty[19] it had to be defined the category for the armament limitation agreement. According to CFE any vehicle is classified as IFV it is has 20 mm or higher caliber gun.

Thanks to the treaty the tracked M113 (below left) is an APC because it is equipped only a 12.7 mm (0.5 cal) M2 Browning gun. The only machine gun equipped wheeled BTR-60, BTR-70 and BTR-80 (below right) are also APCs

The tracked BMP-1 with 76 mm gun is considered as IFV as the later designed BMP-2 with a 30 mm autocannon. Both could be equipped with different kind of guided anti-tank missile (ATGM).The American M2 Bradley is also an IFV which is also have ATGM the BGM-71 TOW family. It is very clear the vehicles in the latter section are very different from the vehicles mention as APCs.

The problem starts with the BTR-80A which is classified as IFV because of its higher caliber 30 mm gun while its armor protection if far less comparing to many other (mostly) tracked and heavier IFV. It has very similar or identical armor with the BTR-80 which is classified as APC.

Regardless both the BMP-2 and BTR-80A are equipped with 30 mm autocannon a BMP-2 with ATGM has such anti-tank capability which the BTR-80A does not have. The BMP-2 in mid '80s with the 9M113 Konkurs ATGM meant a serious threat even for the best first line MBTs (M1IP, Leopard 2A1/4) while the BTR-80A had zero capability against these tanks. Only from the rear could penetrate the armor of any MBT. Regardless of this major difference both are considered as IFV which is a bit hilarious.

It was not common but existed such M113 variant which could mount M47 Dragon ATGM. It means regardless it had only a machine gun and has at least a second line anti-tank capability it still was classified as APC.

The German Puma IFV has 30 mm gun, it is tracked and well armored comparing to Cold War IFVs while it does not have any ATGM. It means easily can deal with BTR-80A or BMP-2. But in case the BMP-2 has Konkurs ATGM the BMP-2 can have range advantage and anti-tank capability while the Puma is just as powerless against a tank as a BTR-80A.

Because of the listed issues above many times the IFV term is useless in "official" way because it can mean very different combat capabilities.

[19] https://en.wikipedia.org/wiki/Treaty_on_Conventional_Armed_Forces_in_Europe

Quick analysis on the air defense of a single army group

Idealized quantity and quality

The inventory of idealized fully armed Soviet units are known. Using this input in first step we calculate an idealized case where every unit is armed on the same level which is considered the nominal Soviet level in a certain era.

Following this step knowing the major difference between the nominal Soviet quantity and the inventory of the NSWP countries it can be examined the real capability of the mixed force of Warsaw Pact. Of course not every Soviet unit were equipped on the same level. The reduced capability also can be true if we consider second line and reserve units of the Soviet Union with less advanced weapons. (In NATO term these were called category II and III units (sometimes B and C) depending on their inventory and personnel.

The army air defense of an army group is calculated with the following conditions in 1980 and 1990, 2000:

- The base case is 1980 considering only the “classical” Cold War equipment:
  - on regiment level are ZSU-23-4 Shilka and Strela-1/10
  - on division level are 9K33 Osa or 2K12 Kub regiment depending on mechanized rifle (MRDv.) or tank division (TDv.)
  - on army level is 2K11 Krug
  - on army group level is 2K11 Krug

- In 1990 is considered partial replacement of the “classical” Cold War equipment:
  - on regiment level are ZSU-23-4 Shilka and Strela-1/10
  - on division level are 9K33 Osa or 2K12 Kub regiment depending on mechanized rifle (MRDv.) or tank division (TDv.)
  - on army level is 9K37 Buk-M1
  - on army group level is 9K83 Sz-300V

- In 2000 is considered full replacement of the “classical” Cold War equipment:
  - on regiment level is 2K22M Tunguska
  - on division level is 9K331 Tor-M1 for both type of division
  - on army level is 9K37 Buk-M1
  - on army group level is 9K81 S-300V

- For every calculations are considered the most advanced equipment variant in that era.
- The missile quantity values are considered **without** the carried reload.
- Every units are deployed.
- Every deviations of NSWP and other additional factors will be addressed later.

Considering all of the conditions of above the calculated nominal firepower of an army group with one mechanized rifle army and one tank army with is calculated with the following compositions:
(2x MRDv.+3x TDv.) + (4x MRDv. + 1x TDv.) = in total 6x MRDv. + 4x TDv. without the reserve division.

It can be considered an army with only Soviet division in case units are within the Soviet Union for example close to Chinese or Iranian border. These were typically second line units with less advanced equipment comparing to Europe. Even for these armies the idealized case remains only fiction.

❖ *Idealized air defense of a full army circa 1980*

1x Krug brigade = 3x Krug battalions = 3x3 = 9x batteries (medium range)
9x target channels
54x missiles

➢ ***2x armies:***

2x Krug brigades= 6x Krug battalions = 6x3 = 18x batteries (medium range)
2x9 = 18x target channels
2x54 = 108x missiles

- ***6x mechanized rifle divisions:***

  6x Osa regiments = 6x5 = 30x batteries = 30x4 = 120x Osa vehicles
  6x(5x4) = 120x target channels
  6x(5x4)x6 = 720x missiles (short range)*
  6x6 = 36x Strela-2/3 MANPAD launchers (division HQs)

  - *6x3 = 18x mechanized rifle regiments:*
    18x4 = 72x ZSU-23-4 Shilka vehicles (short range AAA)
    18x4 = 72x Strela-1/10 vehicles (EO/IR SHORAD) in total 72x4 = 288 missiles
    18x3 = 56x Strela-2/3 MANPAD launchers (regiment HQs)
    - 6x9 = 54x mechanized battalion:
      54x9 = 486x Strela-2/3 MANPAD launchers

  - *6x1 = 6x tank regiments:*
    6x3 = 18x Strela-2/3 MANPAD launchers (regiment HQs)
    - 6x3 = 18x tank battalions:
      It does not have MANPAD defense according to FM 100-2-3 but according to other sources it may have.

- ***4x tank divisions:***

  4x Kub regiments = 4x5 = 20x batteries
  20x target channels
  4x5x(4x3) = 240x missiles (short range)*
  4x6 = 24x Strela-2/3 MANPAD launchers (division HQs)

  - *4x3 = 12x tank regiments:*
    12x4 = 48x ZSU-23-4 Shilka vehicles (short range AAA)
    12x4 = 48x Strela-1/10 vehicles (EO/IR SHORAD) in total 48x4 = 192 missiles
    12x3 = 36x Strela-2/3 MANPAD launchers (regiment HQs)
    - 4x10 = 40x tank battalions:
      It does not have MANPAD defense according to FM 100-2-3 but according to other sources it may have.

* *Regardless Osa (SA-8), Kub (SA-6) and Tor-M1 (SA-15) are classified as "short range" their engagement envelopes are quite different. The Osa and the Tor-M1 have only 5-6 km maximal engagement altitude and their 11-12 km (nominal) range puts them into a strange middle position. They outrange the NATO's radar SHORAD systems (Roland, Crotale) while their range is considerably smaller to 2K12M Kub (SA-6) which can guide missile up to 8-10 km altitude up to 22-25 km distance. The Osa and Tor-M1 are halfway between the IR/RADAR SHORAD and HAWK (with MIM-23A missiles), 2K12 Kub SAM systems.*

❖ *Idealized air defense of a full army circa 1990*

1x S-300V brigade = 4x missile battalions (long range)
24x target channels, 16x normal + 8x ABM
120x missiles, 96x normal + 24x ABM

➢ ***2x Armies:***

2x Buk-M1 brigades= 2x4 = 8x missile batteries = 8x3 = 24x firing units (medium range)
24x2 = 48x SOU = 48x target channels, 48x4 = 192x missiles
24x1 = 24x PZU = 24x8 = 192x missiles

- ***6x mechanized rile divisions:***

  6x Osa regiments = 6x5 = 30x batteries = 30x4 = 120x Osa vehicles
  6x(5x4) = 120x target channels
  6x(5x4)x6 = 720x missiles (short range)*
  6x6 = 36x Igla-1/Igla MANPAD launchers (division HQs)

  - *6x3 = 18x mechanized rifle regiments:*

    18x4 = 72x ZSU-23-4 vehicles (short range AAA)
    18x4 = 72x Strela-10 vehicles (EO/IR SHORAD) in total 72x4 = 288 missiles
    18x3 = 56x Igla-1/Igla MANPAD launchers (regiment HQs)
    - 6x9 = 54x mechanized rifle battalions:

      54 x 9 = 486x Igla-1/Igla MANPAD launchers

  - *6x1 = 6x tank regiments:*

    6x3 = 18x Igla-1/Igla MANPAD launchers (regiment HQs)
    - 6x3 = 18x tank battalions:

      It does not have MANPAD defense according to FM 100-2-3 but according to other sources it may have.

- ***4x tank divisions:***

  4x Kub regiments = 4x5 = 20x batteries
  20x target channels
  4x5x(4x3) = 240x missiles (medium range)
  4x6 = 24x Igla-1/Igla MANPAD launchers (division HQs)

  - *4x3 = 12x tank regiment:*

    12x4 = 48x ZSU-23-4 vehicles (short range AAA)
    12x4 = 48x Strela-10 vehicles (EO/IR SHORAD) in total 72x4 = 288 missiles
    12x3 = 36x Igla-1/Igla MANPAD launchers (regiment HQs)
    - 4x10 = 40x tank battalions:

      It does not have MANPAD defense according to FM 100-2-3 but according to other sources it may have.

❖ *Idealized air defense of a full army circa 2000*

1x S-300V brigade = 4x missile battalions (long range)
24x target channels, 16x normal + 8x ABM
120x missiles, 96x normal + 24x ABM

➢ ***2x Armies:***

2x Buk-M1 brigades= 2x4 = 8x missile batteries = 8x3 = 24x firing units (medium range)
24x2 = 48x SOU = 48x target channels, 48x4 = 192x missiles
24x1 = 24x PZU = 24x8 = 192x missiles

- ***6x mechanized rile divisions:***

  6x Tor-M1 regiments = 6x5 = 30x batteries = 30x4 = 120x Tor-M1 vehicles
  6x(5x4x2) = 240x target channels
  6x(5x4)x8 = 960x missiles (short range)*
  6x6 = 36x Igla-1/Igla MANPAD launchers (division HQs)

  - *6x3 = 18x mechanized rifle regiments:*

    18x6 = 108x 2K22M Tunguska vehicles (short range SAM + AAA)
    in total 108x8= 864 missiles
    18x3 = 56x Igla MANPAD launchers (regiment HQs)
    - 6x9 = 54x mechanized rifle battalions:

      54 x 9 = 486x Igla-1/Igla MANPAD launchers

  - *6x1 = 6x tank regiments:*

    6x3 = 18x Igla-1/Igla MANPAD launchers (regiment HQs)
    - 6x3 = 18x tank battalions:

      It does not have MANPAD defense according to FM 100-2-3 but according to other sources it may have.

- ***4x tank divisions:***

  4x Tor-M1 regiments = 4x5 = 20x batteries = 20x4 = 80x Tor-M1 vehicles
  4x(5x4x2) = 160x target channels
  4x(5x4)x8 = 640x missiles (short range)*
  4x6 = 24x Igla-1/Igla MANPAD launchers (division HQs)

  - *4x3 = 12x tank regiment:*

    12x6 = 72x 2K22M Tunguska vehicles (short range SAM + AAA)
    in total 72x8= 576 missiles
    12x3 = 36x Igla-1/Igla MANPAD launchers (regiment HQs)
    - 4x10 = 40x tank battalions:

      It does not have MANPAD defense according to FM 100-2-3 but according to other sources it may have.

The calculated values above are summarized in the chart below for each era. The quotation marks for some target channel qty. are used for certain units where one launcher or vehicle can engage one target. Target channel is typically interpreted for radar guided SAMs not for anti-aircraft gun of IR SHORAD and MANPAD units but they can be considered as such thing because they can engage the same or different targets as radar guided SAMS.

Idealized air of an army in 1980 (without the reserve division)					
Type	*Target channel qty.*	*missile qty.*	*engagement range*	*engagement altitude*	*note*
2K11 Krug-M1	27	162	6-55 km	0.15-24 km	>800 m/s (even short range BMs)
2K12 Kub-M3	20	240	4-25 km	0.02-8km	
9K33M3 Osa AKM	120	720	1.5-6.5 km 1.5-10 (15)* km 1.5-10 km	0.01-5 km 0.025-5km 0.1-5 km	target speed <100 m/s target speed <300 m/s target speed <500 m/s
9K31 Strela-1 or 9K35 Strela-10M	„120”	480	0.8-5 km	(0.01) 0.025-3.5 km	EO (Strela-1) IR or EO (Strela-10M). one vehicle can engage one target
MANPAD	„672”	„672 ”	max. 4 km	~2-3km	Igla-1/Igla has all aspect capability from 1981, target speed <M1.0. up to 4 km
ZSzU-23-4	„120”	high rate of fire gun	0.2-2 km	0-2 km	radar guided

**See the note about the range of Osa AKM about the chapter of 9K33 family.*

Idealized air defense of an army in 1990 (without the reserve division)					
Type	*Target channel qty.*	*missile qty.*	*engagement range*	*engagement altitude*	*note*
9K81 Sz-300V	16 8 In total 24	96 24 In total120	6-75 km 13-100 km	0.025-25 km 1-30 km	>1700 m/s >2400 m/s (AMB missile)
9K37M Buk-M1	48	192	3.5-35 km	0.015-22 km	target speed <800 m/s
2K12 Kub-M3	20	240	4-25 km	0.02-8km	
9K33M3 Osa AKM	120	720	1.5-6.5 km 1.5-10 (15) km 1.5-10 km	(0) 0.01-5 km 0.025-5km 0.1-5 km	target speed <100 m/s target speed <300 m/s target speed <500 m/s
9K35 Strela-10M	„120 ”	480	0.8-5 km	(0.01) 0.025-3.5 km	IR or EO (Strela-10M). one vehicle can engage one target
MANPAD	„672 ”	?	max. 4-5 km		Igla-1/Igla has all aspect capability from 1981. target speed <M1.0. up to 4 km
ZSU-23-4	120	high rate of fire gun	0.2-2 km	0-2 km	radar guided

Idealized air defense of an army in 2000 (without the reserve division)					
Type	*Target channel qty.*	*missile qty.*	*engagement range*	*engagement altitude*	*note*
9K81 Sz-300V	16 8 In total 24	96 24 In total120	6-75 km 13-100 km	0.025-25 km 1-30 km	>1700 m/s >2400 m/s (AMB missile)
9K37M Buk-M1	48	192	3.5-35 km	0.015-22 km	target speed <800 m/s
9K331 Tor-M1	400	1600	1.5-12 km	0.010-6 km	
2K22M Tunguska	180	1440	2.5-8 km	0.015-3.5 km	target speed <600 m/s
MANPAD	„672 ”	672	max. 4-5 km		Igla-1/Igla has all aspect capability from 1981. target speed <M1.0. up to 4 km

Between the 1980 and 1990 idealized cases we can see the huge impact of S-300V and Buk-M1 on army group and army levels:

- Comparing to a single 2K11 Krug brigade the 9K81 S-300V brigade has about 2.5 times (24 vs 9) more target channels and about two times (120 vs 54) more missiles with larger engagement distance (below 10 km altitude 75 km vs 35 km) and real ABM capability. Even the V1 variant had better ABM capability then the Krug.

  A single S-300V brigade with 24x target channel has almost the same qty. as the three (!) 2K11 Krug brigades. Three Krug brigades was the air defense of an army group and the two armies combined.)

- Comparing to a single 2K11 Krug brigade the 9K37 Buk-M1 brigade has about five (!) times (48 vs 9) more target channels and 3.5 times more (192 vs 54) missiles. Comparing to the Krug the engagement range is smaller (35 km vs 47 km) but this is meaningless because is true only at very high altitude. Against tactical fighters below 10 km altitude their engagement range are the same, at very low altitude the Buk-M1 slightly outranges the Krug.

Between the 1990 and 2000 idealized cases we can see the huge impact Tor-M1 and also the 2K22M Tunguska or lower level.

- Comparing to target channels of the 240 = 120 + 120 Strela-10 + ZSU-23-4 Shilka vehicles the 2K22M Tunguska units provide only 180. For exchange the engagement range of the 2K22M is 8 km comparing to 5 km of the Strela-10M. The total the available missile quantity on regiment level is increased to 1440 from 480 which is 3 times higher comparing to older 1980 state. The available total gun ammo in 2K22M units are less comparing to ammo is ZSU-23-4s in total. This is not a big deal. The main threat from late '80s were the AH-64A + AGM-114 with 8 km range and even older combat helicopters had 3-4 km range ATGM such as BGM-71 TOW or the European HOT missile

- The 9K33M3 Osa regiments are replaced with 9K331 Tor-M1 have the same vehicle quantity but each vehicle has two target channel instead one and 8x missiles instead 6x. A Tor-M1 regiment has 25% more missiles and double target channel quantity comparing to Osa.

- The 2K12 Kub regiments are also replaced with Tor-M1 regiments. Comparing to 60x missiles/Kub regiment a Tor-M1 regiment has 160 missiles ready to launch. Comparing to 5x target channels of Kub a Tor regiment has 40x which is 8 times (!) higher.

The 9K331 Tor-M1 has much smaller engagement range (ca. 12 km) comparing to Kub (ca. 20 km). It is clearly seen result of the experiences of Cold War conflicts in its design. Increasing the available missiles without reload was a very high priority. For a single hit many missiles had to be launched against fighters because of their maneuverability and other factors on the battlefield.

Because of the 4th generation fighters with better flight performance also was priority providing missiles with better maneuverability. In pervious conflicts even 2nd and 3rd generation fighters many times dodged/outmaneuvered the missiles.

During the '80s even AGM and laser guided bombs typically were used at low or medium altitude therefore the high altitude engagement capability of the 2K12 Kub was not so important comparing the Tor-M1 what is limited to 6 km.

Another factor for replacing with Tor-M1 the Kub was the SEAD activity with more and more advanced anti-radiation missiles. All SAMs with a single target channel had only one option in case of incoming ARM. Turning off the radar. With the Tor-M1 (and Buk-M1 and S-300V) target channels can be allocated for self-defense against ARM while still is possible to engage other targets.

Layers and coverage areas of the army air defense of the WPACT

Judging by the pure numbers of an idealized army group composition it may seems at first sight that army air defense of a WPACT army group is close to being impenetrable even with 1980 nominal equipment. If we calculate with the 1990 or 2000 idealized inventory the situation is even worse for any attacker. But the numbers alone are misleading because are lots of factors which have impact on the effectiveness of the capability of air defense. Another "minor" issue is the real inventory of both Soviet and NSWP units comparing to nominal (idealized quantities).

Dealing with the threat of the WPACT air defense the NATO planned with strong electronic warfare (jamming + decoys), flying at very low altitude (30-100 m) even at night (with terrain following radar) in combination using anti-radiation missiles (ARM) with concentrated air power usage. The terrain and low level flying seriously restricts the possibility of continuous target tracking capability using radars. At night in Cold War literally every EO/IR guided system did not have night time combat potential because for launch targets had to be visually spotted and tracked not mentioning the visual identification to avoid friendly fire.

In the age of single target channel radar system the suppression by the ARM was very powerful many times the only option was turning off the fire control radar. As we have seen now a full 2K12 Kub (SA-6) regiment has only 5 target channels. If only one battery is in relocation phase by suppressing just one SURN the firepower of the whole regiment is decreased with 25%. Meanwhile all of the missiles the suppressed battery is disabled for a while which can mean even twelve missiles. Regardless the lots of available radar guided air defense missiles on paper only a very few ARM can seriously reduce the quantity of available target channels and missiles at least temporary. If the fire control radar is destroyed the reduction is even more serious.

It is also not guaranteed even with supporting elements of the IADS that target channel allocation is perfect. Maybe some airplanes are targeted by more than one unit which means less target are distracted by the air defense.

This is why is a big deal the 2K12 Kub-M3 ---> 9K331 Tor-M1 replacement and was the delayed development of the 9K33 Osa. The firepower and targets channels are more distributed and there is more reserve in the system.

The case is the same on army level with 2K11 Krug-M1 ---> 9K37 Buk-M1 replacement. The Buk-M1 has much more target channels. Even one of the TELAR is destroyed or disabled a firing unit loses only half of the firepower and battery loses only 1/6th (16%).

Both of these "double digit" radar SAM systems make much harder to destroy or even suppressing the medium range radar guided air defense.

S-300V is partially an exception because regardless of the many independent CW emitters on TELARs without the Grill Pan radar the firepower of a missile battery is **zero**. A single Buk-M1 firing unit is able to launch missiles two opposite directions because of the two TELARs. A single BuK-M1 battery can have even 360 degree coverage (6x TELARs) while the missile battery of the S-300V has only 90 degree launch arc with a crucial radar for operation.

Another factor is the point of the army air defense. It has to protect troops during combat and movement. A part of the air defense is always in different phase of relocation. The 2K11 (SA-4) and 2K12 (SA-6) have about 15 minutes deployment time which has to be considered. Against highly maneuverable tactical fighters and strike fighters using Cold War system many missiles had to be launched to have slight chance for success. This means in an intense combat environment the available missiles on rails of in canisters quickly can be depleted. The reload takes long time even for IR/RADAR SHORAD units before they can rejoin to the combat.

The terrain can restrict the potential useful spots for deployment – it is impossible to track target and launch from the woods and from a volley is may hard to find a place where the slopes do not block the radar coverage.

The size of the theater in combination with terrain have very big impact on the density of the target channels. If the available target channel quantity in an area is low with limited range it makes much easier to saturate the air defense. One army group can act along a 200-250 km long part of a theater with 20-50 km depth. There is simply no guarantee that movement of combat units and the topography make possible such nice deployment which is shown **as very idealized example** below.

The attacker airplanes can fly to their targets low which decreases the time which is available for spotting, tracing and identification. EO/IR missiles can be defeated with flares, radar guided missiles with jamming and chaff and also these can be combined with maneuvering defeat.

The speed of airplanes far exceeds the relocation speed of land based air defense. The center of an air strike/attack much quicker can be changed (based on recon data) comparing to the position of the air defense. Of course the air cover of the ground forces also can be enusred by fighters not only by the land based air defense.

Considering everything above on the diagrams below on the following pages are shown an attacking force with 2x24 airplanes which is two nominal USAF squadrons. This is not an imaginary attacking force during the Desert Storm were used such large packages. In the operation area of an army group (200-250 km wide zone) it is not an overstatement assuming 200 attacking airplanes and helicopters with stand-off jamming and other support assets. Inside the engagement zone of an army could be 100 scale aircraft. This is why command posts and other communication elements in the IADS are crucial for the effective use for air defense. These systems are in IADS equipment of Army Air Defense chapter.

With the following considerations are illustrated the available target channels and coverage the air defense of an army group. The values are on the diagrams are quantity of the available target channels/circle:

- The three firing batteries of an 2K11 Krug are merged into a single point. The maximal distance between the batteries can be 5 km therefore comparing to the unit in the center the engagement zone difference is small.

  From the three firing battalions only two are deployed the remaining third is in relocation state.

  The army group level Krug battalions are equally divided between the two armies.

  35 km engagement range is considered. Against tactical targets (below 10 km) the range is only 35 km, see the engagement zone of the Krug in its detailed description.

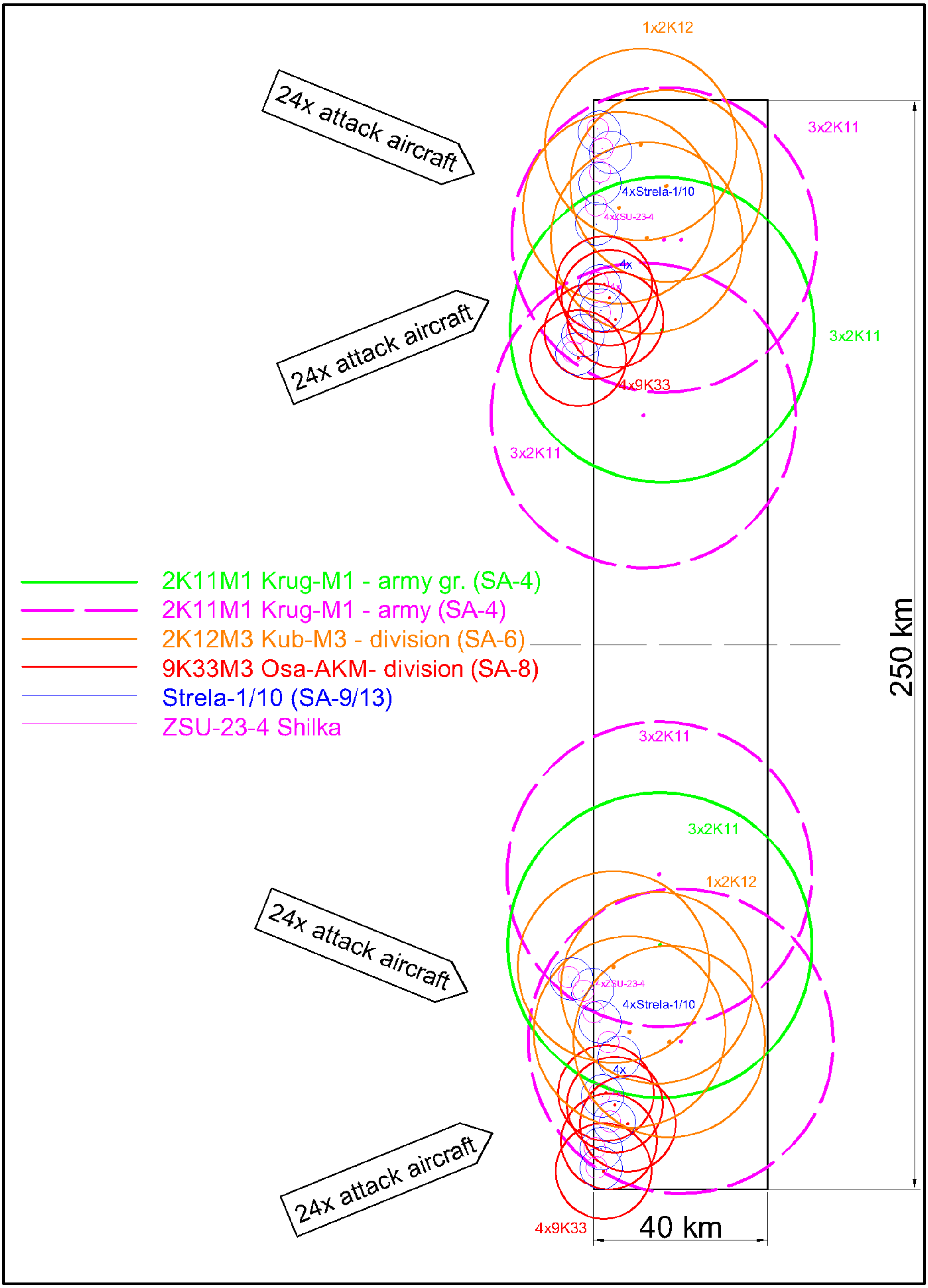
- Each 2K12 Kub battery is displayed independently. From the five batteries one is in relocation state for an armored division. Engagement range is 22 km.
- The pair of 9K33 Osa (half platoon) escorts a single attacking battalion in mechanized division 1.5-3 kilometers behind the combat units. The reserve battalions of regiments do not have air defense.

  The distance between the vehicles is about max. 1 km, between the battalions about 3 km. Because of the small distance the engagement zones of four 9K33 Osa are merged into a single point. From driving following a stop less than 20 seconds is needed the achieve the ready to launch state, therefore every vehicles is considered available. Engagement range is 11 km.
- The pair of 9K31 Strela-1/9K35 Strela-10 (half platoon) escorts a single attacking battalion in mechanized division about 0,5-1 km behind the combat units. Because from driving following a stop less than 20 sec can be achieved the ready to launch state every vehicles is counted as ready to launch. Engagement range is 5 km.
- ZSU-23-4 is similar the case of Strela-1/10. Engagement range in 2.5 km.
- The MANPADs are not displayed because their quantity would make unreadable the diagram and their dispersion even more random.
- On the drawing one mechanized and one tank division are displayed for both armies to see the difference between the Osa and Kub equipped divisions.
- Only two divisions are placed because they are enough to see the idealized overlapping engagement zones of lower and higher level air defense units. On the second diagram is shown with a higher magnification the engagement zones of the two divisions.
- The effect of altitude is neglected. The EO/IR SHORAD and MANPAD weapons has less engagement altitude than 3.5 km.
- **Nuclear weapons are not used.**
- The land based air defense and fighters do not act in the same In the same airspace because of the high chance of friendly fire. Because of both the limitation of the BVR electronic IFF (many targets in the lobe of IFF system) and visual identification limits chance of safe engagements.

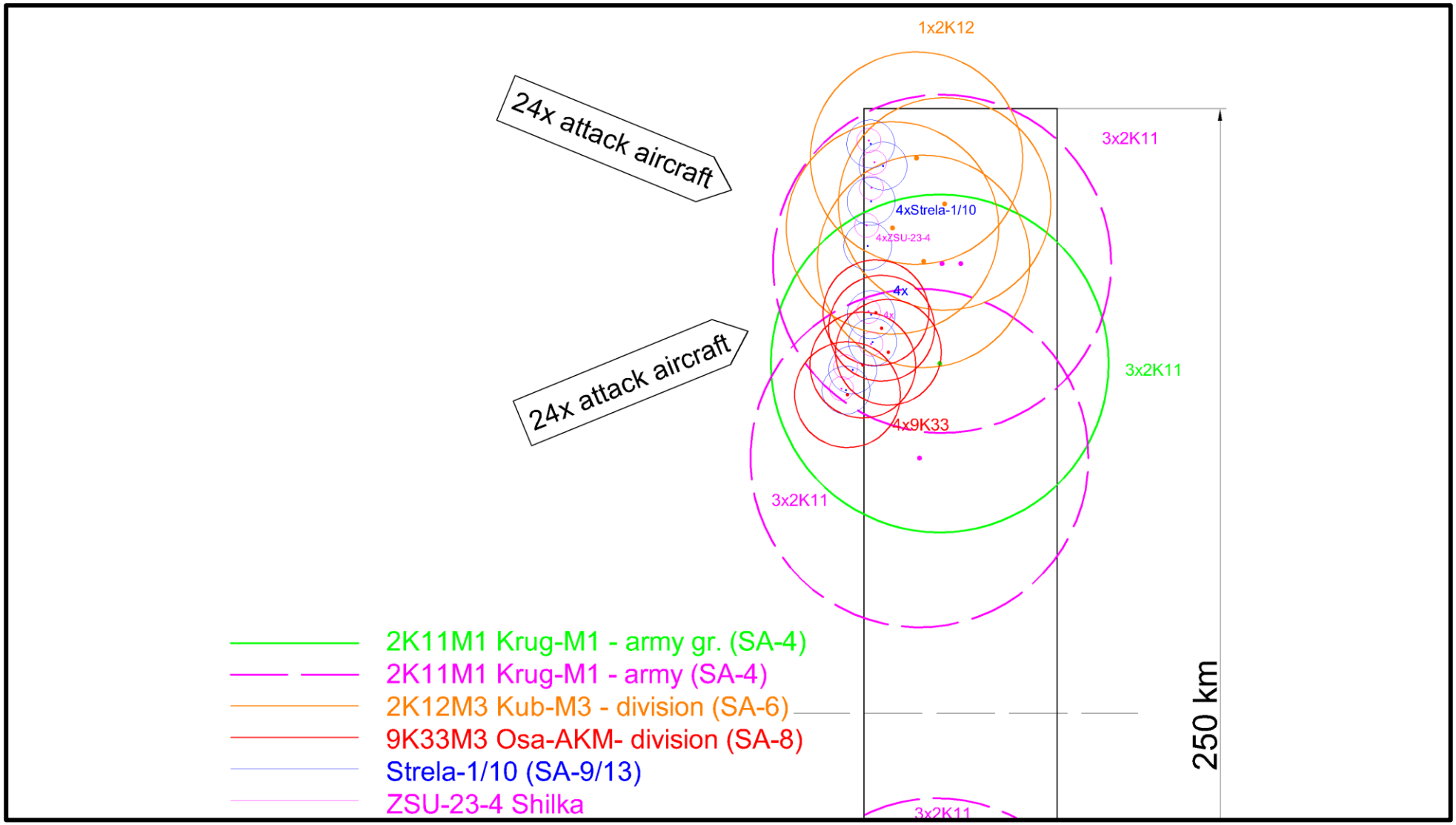
Of course the layout diagram is very fictional. It is very unlikely that every divisions can form such a nice straight line during the advance. The point of the diagram is help to imagine and calculate a certain set-up with available target channels and missiles.

On the first image we can see at maximal engagement range with considering only a single squadron size force only 3-6x Krug target channels are available besides the 2-3x Kub batteries. They can engage 5-9 targets while 24x aircraft attack the tank division. Comparing to the 24x incoming targets this is not so much even without considering any other factors. Flying at very low, the terrain and jamming simply can deny the long range engagement before the attacker get really close (<20 km about 1 minute flight time) to their targets.

The really dense target channel zone happens when airplanes enter into the engagement zone the engagement zone of the 9K33 Osa + ZSU-23-4 Shilka + 9K31/35 Strela-1/10 + MANPADs. The mechanized rifle divisions equipped with Osa have much more target channels than tank divisions. The less advanced strike airplanes with dumb bombs and rocket have to deal every kind of threat what the army air defense.



Idealized air defense of an army group in 1980. Only with two divisions, one mechanized infantry and one tank division are shown.



Idealized air defense of an army in 1980. Only with two divisions, one mechanized infantry and one tank division are shown.

The more advanced strike/attack airplanes fighters with longer range air to ground missiles such as A-10A + AGM-65D in favorable cases can stay outside the engagement zone of the ZSU-23-4 Shilka and maybe Strela-1/10. With 5-7 km AGM-65 launch distance at 2 km altitude they can operate edge of engagement zone these systems which mostly follow 1-2 km behind the defended units. The A-10A has more than a hundred of flares which provide a very good survivability against older IR/EO SHORADs and MANPADs. The older EO/IR missiles had very limited all aspect capability or not at all. The 9K33 Osa and 2K12 Kub have decent engagement ranges comparing to any AGM or laser guided bombs (LGB) in the '80s. Their missiles are enough agile even against 4th generation fighters on paper especially the Osa is good in this area.

Less advanced second line airplanes type are less lucky because they mostly lacks good RWR, ECM and/or dispensers for self-defense. The chance of survival is very different sitting in an A-10A attack plane equipped with ECM pod and dispenser supported with EF-111A Raven (stand-off jammer) and escorted by an F-4G (SEAD escort) comparing to a Fiat G.91 Gina without any support...

Of course not only the A-10 but other jets also could carry AGM or LGB and had ECM and dispensers. It was just an example to understand the features of the target which can make less effective the air defense.

In case we replace the 2K11 Krug with 9K37 Buk-M1 and 9K33 Osa AKM regiments with 9K331 Tor-M1 the available target channels become much higher with much better general coverage especially if we consider an 9K81 S-300V long range SAM. Using the 1990 idealized state we consider the followings changes comparing to 1980:

- The six firing units of an 9K81 S-300V battalion are merged into a single point. The maximal distance between the batteries can be 5 km therefore comparing to the unit in the center the engagement zone difference is small.

  S-300V battalions are equally divided between the two armies 2-2 for each.

  From the two battalions only one is deployed the remaining is in relocation state. Engagement range is 75 km.

- The three firing batteries of an 9K37 Buk-M1 battalion are merged into a single point. The maximal distance between the batteries can be 5 km therefore comparing to the unit in the center the engagement zone difference is small.

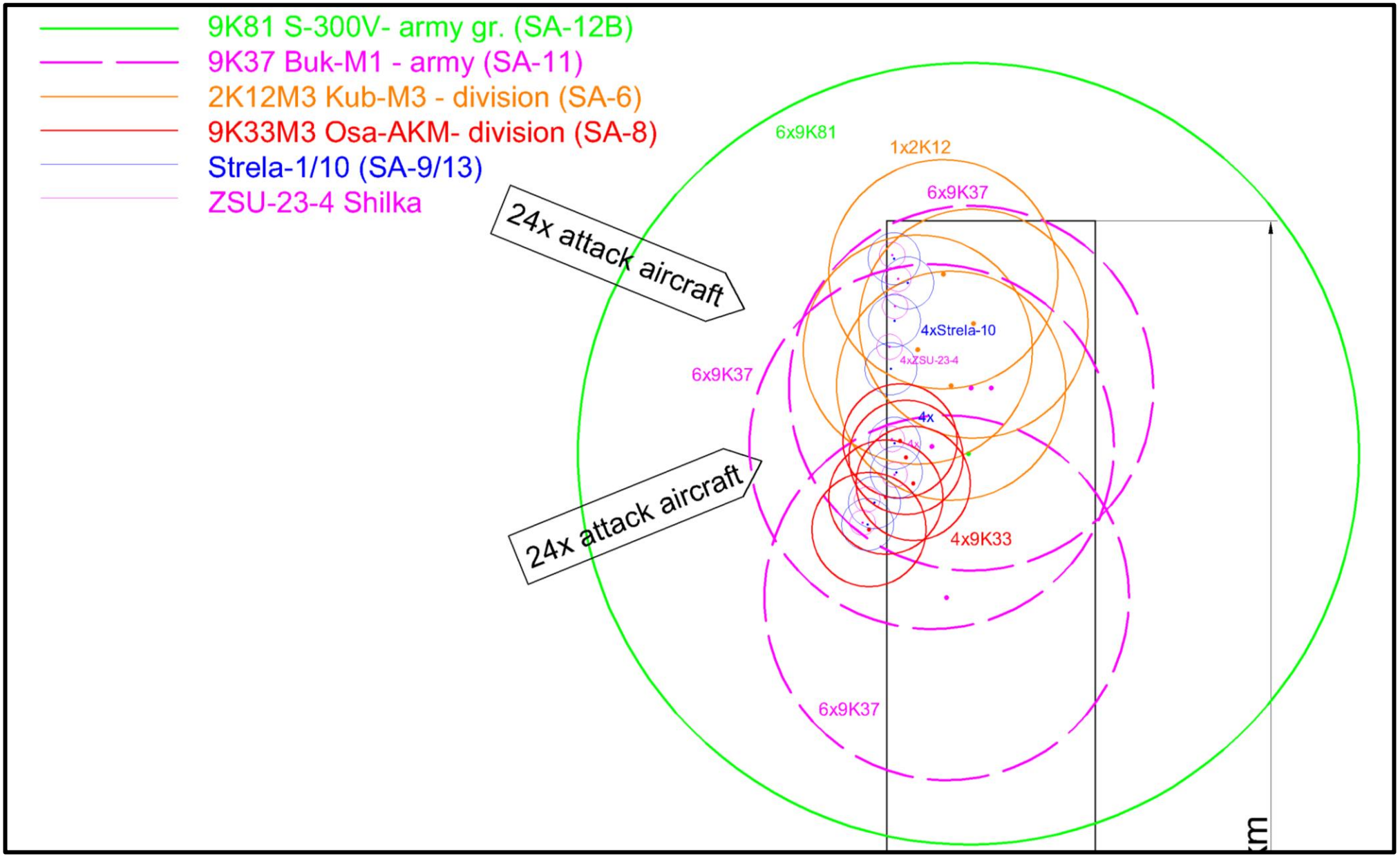
  From the four battalions only three are deployed the remaining fourth is in relocation state. Engagement range is 35 km.

On the image below we can see at maximal engagement range the S-300V can start engaging targets much larger distance comparing to nominal 1980 set-up with six target channel. At the same distance where in 1980 Krug units can provide 3-6x target channels the Buk-M1 units provides 2x6 = 12 with anti-ARM capability. The long range engagement capability on army level is on a totally different level counting the maneuverability and speed (which reduces the time to react) of the missiles as well as the anti-SEAD capabilities and available missiles.

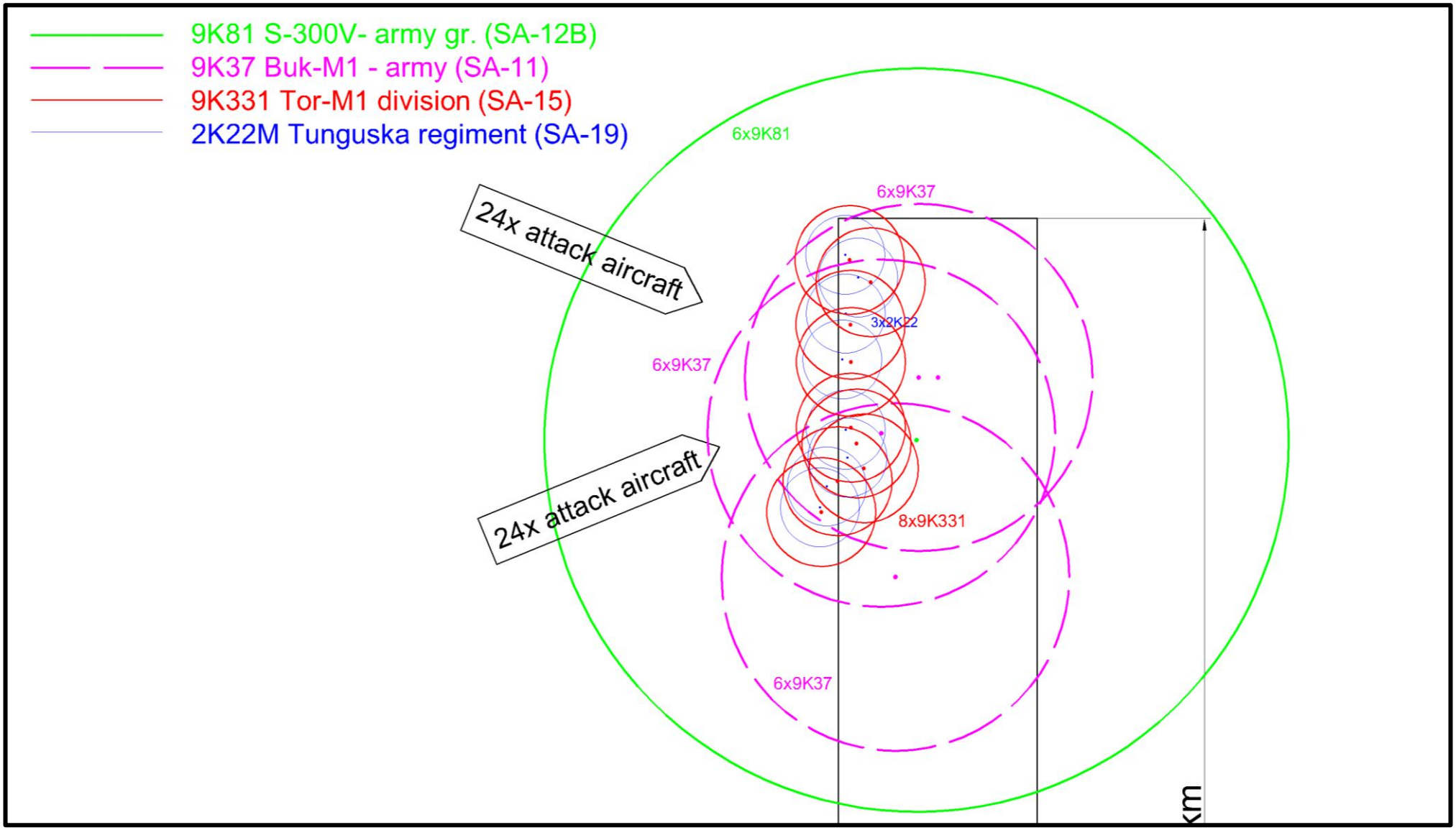
With 2000 idealized state we consider the followings changes comparing to 1990:

- 9K331 Tor-M1 quantity and location are the same as 9K33 Osa just with double target channel quantity. Engagement range is the same as Osa has. Tor-M1 regiments replace both the 9K33 Osa and 2K12 Kub regiments.

- 1+1 Strela-10 and ZSU-23-4 units are replaced and merged into a single 2K22M unit with 3xTunguska vehicles. Engagement range is 8 km.



Idealized air defense of an army in 1990. Only with two divisions, one mechanized infantry and one tank division are shown



Idealized air defense of an army in 1990. Only with two divisions, one mechanized infantry and one tank division are shown

We can see depending on the era and equipment the engagement zone and available targets channels which cover a single regiment can be very different. Of course many regiments can be within the engagement zone of a single S-300V or 2K12 Krug unit. If we add the target channels for a certain regiment these long and medium range systems it means the rest are not covered by them.

The chart below shows the maximal value for an idealized regiment. If a regiment is outside from the engagement zone of army or army group level SAM units their target channels have to be subtracted.

	1980	1990	2000
2K11 (SA-4)	3-6		
9K81 (SA-12)		6	6
9K37 (SA-11)		6-12	6-12
2K12 (SA-6)	0-2	0-2	
9K33 (SA-8)	4	4	
9K331 (SA-15)			8
2K22M (SA-19)			6
9K31/9K35 (SA-9/13)	4	4	
ZSU-23-4	4	4	
Total target channels	15-21	24-32	30-36

Calculated target channel coverage in idealized state for idealized regiments.

Deviations from the Soviet army air defense in NSWP countries

Now we can see how fantastic it would look a fully equipped up to date Soviet army air defense in a certain era. The problem the reality was much different. In NSWP countries even the first line units lacked many cases the nominal quantity from certain weapon systems (as well as the second line and reserve Soviet units). In the attachments is the "*WPACT-air-defense-acquisitions*" Excel table which contains the data about the quantity and the year of the air defense of the NSWP countries for each combat division or brigade and acquisition dates.[20]

Only three NSWP countries are listed below in detail because even these are enough to show the difference between the idealized inventory and the harsh reality.

Deviations of the Hungarian air defense comparing to idealized quality and quantity:

- The direct air defense of the a battalion was only half of the Soviet. Only 4+1 MANPAD launchers were per battalion instead 8+1 (+1 is the commander). Even in the late '80s 9K32 Strela-2M (SA-7) rear aspect was the prevalent. In total 1540 missiles were fielded from 1977. From 1986 9K38 Igla-1 (SA-16) became available but only for three regiments (14th, 15th and 33rd see on structure and organization diagram at the beginning of current document) in the whole 5th army.

- The air defense on regiment level was only half of the nominal. Instead 1+1 platoon of ZSU-23-4 + Strela-1/10 a regiment had only one of them.
    - Tank regiments had one platoon of ZSU-23-4 with 4x vehicles and lacked the 9K31/35 Strela-1/10 platoon. (None of them was amphibious.)
    - Mechanized rifle infantry regiments had one platoon of 9K31 Strela-1 or 9K35 Strela-10M (both are amphibious as BTRs and BMPs) but lacked the ZSU-23-4 platoon. In total only four (!) Strela-10 vehicle were acquired by Hungary only for a single battalion (at Szombathely).

[20] *The table was made by Hpasp I only reedited a bit for easier reading.*

- Hungary never fielded the 9K33 Osa (SA-8) system. A division or brigade[21] which had missile air defense following the arrival of 2K11 Krug (SA-4) may had 2K12 Kub (SA-6) but not all of them and none had a full regiment. The Kub units had only 4x or 3x batteries per division. The division which lacked the Kub had only air defense artillery regiments or nothing at all before the acquisition of the Krug system.

- Army level air defense was supported until 1981 by 2K12 Kub (SA-6) instead the 2K11 Krug (SA-4). Before the arrival of Krug was no division level missile defense at all. Following the acquisition of the Krug the available Kub units were forwarded to divisions/brigades.

  Even the acquisition of the Krug system was less than nominal air defense brigade. Hungary had only a Krug regiment. Comparing to the full brigade the unit had one less firing battalion, only 2x instead 3x. This meant a full Krug regiment had only 6x target channels and not 9x. In case one of them in relocation instead 6x only 3x target channels were available.

- On the structure and organization chart (at the early part of current document) we can see that 7th division of the 5th army had only air defense artillery regiment (AAA regiment) which was equipped only S-60 anti-aircraft guns. One regiment had 1x command battery and 4x artillery batteries. The command battery had 2x P-15 (Flat Face) radars for target acquisition and each artillery battery has 1xSON-9 or RPK-1 fire control radar with 6x S-60 air defense guns. A full S-60 regiment had 4x6 = 24x 57 mm caliber guns.

  In the attached Excel table about acquisitions of NSWP "4" means a AAA regiment and "6" AAA brigade. At the end of the Cold War East Germany used AAA brigades. Very likely the first line units which got air defense missiles forwarded their equipment to second line/reserve units and boosted their sizes.

- The army group level air defense was given by Soviet forces.

In Hungary were two armies, one Soviet and one Hungarian. The army level air defense of Hungarian forces considering above was only a 2K12 Krug regiment in mid '80s.

The Southern Group of Soviet Forces (SGSF) had its own army level air defense.

In WPACT in Hungary appeared first the 9K37 Buk-M1 (SA-11) which replaced the 2K11 Krug (SA-4) from 1987. The Buk-M1 had four missile batteries with the following locations: 2x at Mór, 1x at Pápa and 1x at Fertőszentmiklós.

The army group air defense was given by a Soviet 2K11 Krug brigade with the following locations: 1x Dunaföldvár, 1x Igal and 1x Sármellék.

Considering the list above we can say the quality and quantity of the air defense of Hungarian forces even in the '80s following major upgrades seriously lagged behind the Soviet level. This was true not only for air defense but considering every equipment in general (IFVs. ATGMs, tanks, etc.).

This status was not extraordinary among the NSWP countries. In some areas Hungary was superior comparing to for example to Romania. The latter never had 2K11 Krug. East Germany was better comparing

[21] *See in the attached Excel table. From 1987 Hungary adopted the corps-brigade system which replaced the division-regiment.*

to Hungary because it acquired lots of 9K33 Osa (SA-8). Czechoslovakia was contradictory because it had two full Krug brigades and also Osa regiments but had almost no air defense of regiment level.

Considering the diagrams above in 1980 the differences are the following comparing to idealized air defense:

- One 2K11 Krug is in relocation which means only a single firing battalion is available. Is a much higher chance that a regimen is outside the coverage of the system. Even in best case we can speak about 0-3x available target channels.
- There is only ZSU-23-4 or 9K35 Strela-10 which means four less target channels for a regiment and tank regiments had only very short range (<2.5 km) AAA defense.
- 9K33 Osa was not available at all only 2K12 Kub. In best case this would mean 5x target channels per division instead 20x. As we noted above only 3-4x batteries were available per division. This means 0-1x available target channels. Many divisions did not have Kub at all and had only S-60 AAA artillery regiment.

The chart below compares the available target channels considering the engagement range, coverage and other mentioned factors above. The result is quite shocking. This large quality and quantity difference made viable to use second line airplanes all across the NATO. In case the air defense of first line units have been depleted or could be avoided even less advanced aircraft could deal the threat of army air defense.

	cc. 1980 nominal Soviet mech. rifle.	cc. 1985 Hungary mech. rifle.	cc. 1985 Hungary tank.
2K11 (SA-4)	3-6	0-3	0-3
2K12 (SA-6)	0-2	0-1	0-1
S-60 AAA regiment		if 2K12 is not avail.	if 2K12 is not avail.
9K33 (SA-8)	4		
9K31/9K35 (SA-9/13)	4	4	
ZSU-23-4	4		4
Total target channels	15-21	4-7	4-7

Regardless it never happened it is worth to examine one of the cancelled SAM acquisition of Hungary. It was planned the acquire the 9K37 Buk-M1 in the mid '90s but only a single missile battery was offered only **1/4th part of a full Buk-M2 brigade**. Comparing to this cut the 2/3rd relation between the Krug brigade and battalion was not so serious. This is a clear indication how dire was the financial situation of Hungary following the acquisitions of the '80s.

In '80s only one squadron of MIG-23MF was bought (instead ML or MLD) while the air component of the army had many MiG-21 squadrons. (Hungary in total acquired 50 MiG-21MF and 15+17 MiG-21bis A and MiG-21bis AP variants besides the older PF and F-13.)

Only 25th tank regiment at Tata got T-72M1 tanks rest of the army had only T-55 variants. Regardless Hungary had T-55AM never acquired the gun launched ATGMs.

Deviations of the Czechoslovakian air defense comparing to idealized quality and quantity:

- From the total ten divisions **only three had missile air defense on regiment level**. The regiments had only Praga vz. 53/59[22] self-propelled AAA gun instead the ZSU-23-4 Shilka. The firepower and the accuracy of this vehicle was nowhere close to the radar guided Shilka.

  The AAA above and the Strela-1/10 units composed the regiment level air defense but until acquiring the 44x Strela-10M between 1983 and 1986 only four Strela-1 were bought in 1978. **This means was not missile air defense on regiment level at all before the Strela-10M.**

- From the 10 divisions five had the full division level air defense (20x Osa or 5x Kub batteries per regiment) **but only after 1986**. From the remaining divisions one had 4x Kub batteries, the rest four had only S-60 AAA regiments. In 1980 the date of first idealized examination only two divisions (2nd and 19th mech. inf.) had the full Kub regiment. The only Osa regiment was also missing.

- The army group level Krug brigade defense was available from 1976 but on army level never happened. Until the end of Cold War the shorter range Kub regiment was used which meant only 5x target channels per regiment instead 9x of a Krug brigade with smaller engagement zone.

Considering all the factors above **only one Czechoslovakian division** had the same quantity of target channel as Soviet division but with less quality because of the Praga vz. 53/59. Even this inventory was available only from 1984. The best division had almost as good air defense as a Soviet unit, two other divisions were similar to Hungary with more 2K12 Kub and 2K11 Krug but much weaker short range AAA but the rest seven division **were below even the Hungarian level without Strela-1/10 or ZSU-23-4**.

	1980 nominal Soviet mech. rifle.	cc. 1980 Czechoslovakian mech. rifle.	cc. 1985 Czechoslovakian mech. rifle.
2K11 (SA-4)	3-6	3-6	3-6
2K12 (SA-6)	0-2	0-1	0-2
S-60 AAA regiment		if 2K12 is not avail.	if 2K12 is not avail.
9K33 (SA-8)	4		4[B]
9K31/9K35 (SA-9/13)	4		4[C]
ZSU-23-4	4		
Praga vz. 53/59		4	4
Total target channels	15-21	7-10[A]	15-21[B] 11-17[C] 7-10[D]

A Regardless the quantity is higher comparing to Hungarian 1985 state the quality is lower because of the Praga vz. AAA. The latter is far less potent comparing to a ZSU-23-4 or Strela-1/10.

B Only the 1st tank division of the 1st army had the presented target channels with the Osa. This is a very extraordinary case where a tank division had 9K33 Osa regiment instead 2K12 Kub.

C The remaining second best two divisions had only the Strela-10 units.

D The remaining seven divisions had the same regiment level air defense as in 1980. Only Praga AAA. Regardless of more target channels because of the Praga vz. AAA there were not better than average Hungarian divisions.

[22] https://en.wikipedia.org/wiki/M53/59_Praga

Deviations of the East German air defense comparing to idealized quality and quantity::

- Similarly to Hungary on army level was only a 2K11 Krug regiment 2/3rd of a Krug brigade. East Germany had two armies therefore acquired the two regiments in 1978 and 1980.
- On division level only the 7th and the 9th tank divisions had the full 2K12 Kub regiment. Two mechanized rifle divisions had full 9K33 Osa regiments but only from 1984 (8th div.) and 1988 (11th div.). From the rest of seven divisions (both tank and mechanized infantry) three had 2K12 Kub regiment but only with 4x batteries and the remaining four divisions had only S-60 AAA brigade in 1988.
- On regiment level the defense was simply terrible. About quarter of the regiments had both the 4+4 ZSU-23-4 + Strela-10 the rest has mostly one of them or none of them. Only the best two equipped divisions had the best units.
- On battalion level even at end of Cold War almost exclusively the Strela-2M (SA-7) was available.

	1980 nominal mech. rifle.	cc. 1988 East German n mech. rifle.
2K11 (SA-4)	3-6	0-3
9K81 (SA-12)		
2K12 (SA-6)	0-2	0-2
S-60 AAA brigade		if 2K12 is not avail.
9K33 (SA-8)	4	4[A]
9K31/9K35 (SA-9/13)	4	4[B]
ZSU-23-4	4	4[B]
Total target channels	15-21	12-17[A] 8-13[B] 0-9[C]

A Only the best two divisions had the presented target channels with the Osa. These were the 8thand the 11th divisions.

B Roughly the two second best divisions had both the Strela-10 and ZSU-23-4

C The remaining divisions without the Strela-10 and ZSU-23-4 and typical 1980 German division.

Summarizing the quality above the three NSWP nations. On army and division level the NSWP countries at the end of '80s more or less reached the 1975-80 year Soviet state except where was Kub (SA-6) instead Krug (SA-4) or were less Krug only a regiment. But for the divisions this was not true only about 1/3rd or 1/4th of the NSWP division had fully armed air defense. On regiment and battalion level air defense the difference was even more pronounced. Regardless the "target channels" were available for certain units generally they were less advanced.

For example the whole NSWP used almost exclusively the Strela-2M (SA-7) MANPAD and only a very few Igla-1 (SA-16) were exported into Hungary and East Germany but. Czechoslovakia and Poland did not field the Igla-1 they had only Strela-2M. Igla (SA-18) was cleared for export following the collapse of the Soviet Union. Hungary and in many second line units had half quantity of launchers than the nominal.

Comparing to idealized inventory with lots of target channels the reality was much different. In general in the whole WPACT was far less air defense equipment than the nominal/idealized. As a rule of thumb can be used every information above how strong was the difference. This rule is true also concerning on the rest of equipment (tanks, artillery, air force, etc.).

For example in Hungary the 15th division in at Nyíregyháza did not have artillery support regiment and tank artillery battalion. We are talking about **not less or lower quality equipment they simply did not have them at all**.

The idealized 1990 and 2000 inventories are pure fictions. Maybe in an alternate universe and history they would existed. In reality until 1990 only one S-300V (SA-12B) brigade replaced the 2K11 Krug (in East Germany) and only two 9K37 Buk-M1 (SA-11) brigades, one in Hungary and one in East Germany. In total were about 10 armies along the East Germany- Czechoslovakia-Hungary line and only two got the Buk-M1 upgrade. From the four army groups only one got the S-300V. The 2K22M Tunguska (SA-19) and 9K331 Tor-M1 (SA-15) reached the production status following the Cold War but because of the collapse of the Soviet Union the production rate was very low.

For getting a good picture about the rate of replacement in general it provides a good source the inventory if an elite tank division at Moscow in 2017. It was equipped with T-80UK, BMP-2, BTR-82A, BRM-1K, BM-21 Grad, 9K57 Uragan, 2S19M2 Msta, 9K331M Tor-M2 and BREM-1. Only the Tor-M2 and the BTR-82A are the new items in the inventory but the rest is roughly the idealized armament of a Soviet unit from the late '90s. In 2017. In the Armija 2017[23] we could even ZSU-23-4 Shilka is used equipped with Igla missiles as well as Strela-10M. Today we can say the Tor-M1 and different versions of Buk-M are prevalent in Russian but S-300V is still today is limited to only about five brigades in total while Russia has many military districts...

If anybody thinks the difference in equipment quality existed only between the Soviet Union and NWSP countries is quite naive. The situation was the same in the NATO either comparing to European countries to the USA.

The most advanced and numerous units were the American in the NATO. The other NATO member countries at least in the mid '80s had some advanced equipment but not in every area and not every country. In the large force of the NATO were in big proportion much less advanced or even outdated weapon similarly to NSWP countries.

On forums many times is amusing to see about the arguments pro and con about what would happen if a West German Leopard 2A4 equipped brigade would clash a Soviet T-64BV brigade or any first line Soviet tank unit. But only the best German units had these Leopard variants even in mid '80s. Most of minor European NATO countries used Centurion (which has very strong World II roots in it design) and Leopard 1 tank variants. United Kingdom had a one generation newer Chieftain tank and only some Challenger I. The French AMX-30 was totally outdated as MBT it was rather a recon tank...

In the WPACT we can see the same. The Soviet Union in early-mid '80s had the T-64BV, T-72B, T-80U tanks while the NSWP countries relied on T-55/55AM and only about 10-20% of their forces were composed by the T-72. But not the T-72B with ATGM with much better armor. For NSWP only much less capable T-72 variants were exported. The export of T-64 and T-80 tanks was out of option during the Cold War.

Not only the tanks itself but their ammo also was second line category. The best APFSDS shells would be given from Soviet inventory to NSWP forces in case of a war and only about a dozen or half a dozen per vehicle. Any NSWP regiment/brigade was simply no match to a unit equipped with Leopard 2A1/4 or M1IP/M1A1 unit. Comparing to the armor penetration capability NATO's of ATGMs of '80s (HOT I/II, BGM-71 C/D) the tanks of NSWP were almost unprotected with the few exception which has ERA such as Kontakt-1.

[23] https://legiero.blog.hu/2017/08/29/akcioban_a_pvo

The point of the NSWP units were be able to deal with the forces of minor NATO or neutral states. For example the Hungarian T-55AM and T-72M1 were more than adequate against Italian Leopard 1 and Austrian AMX-13 or M60 tanks.

The inventory comparison for air forces is just the same. It looks very shiny and powerful the USAF F-15 Eagle and F-16 Falcon fleet of the NATO. But besides these in late '70s or even mind '80s lots of F-104 Starfighter, F-5 Tiger II and even subsonic jets were used such as Alpha Jet or Fiat G.91. In case of war even these would fly strike missions because of the sheer size of the ground force of the WPACT. But against reserve units even these older and less capable airplanes would be useful.

In Hungary in the mid-late '80s three Soviet fighter regimens were stationed with 60-90 airframes (the MiG-23s at Sármellék were the last replaced with MiG-29s). Comparing to Soviet forces the most advanced Hungarian fighter was the MiG-23MF and only a single squadron was acquired (12x one seater and 2x training two seater variant). Every other units used the MiG-21bis and MF fighters in total about 110 were acquired. It is not an overstatement that the Soviet MiG-29 9.12 and 9.13 units simply outclassed and had larger fighting power the whole Hungarian air power even considering only 60x Soviet MiG-29s.

While the Soviet Union stationed Su-24 and MiG-27 units with precision guided munitions and SEAD capability Hungary had a single Su-22M3 squadron.

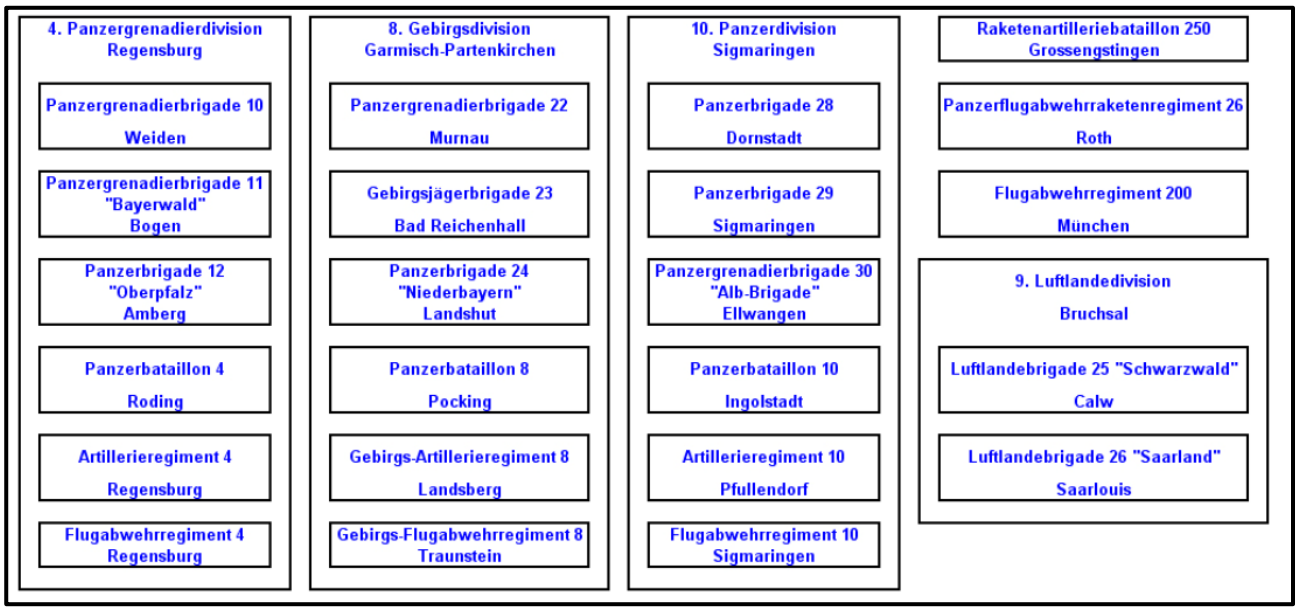
If we check the force composition and judge the numbers well we can conclude the two superpowers provided most of the quality firepower and advanced units in their military alliance. The units of minor states were only gap filling units with only few exceptions.

Side note: The less military expenditures were the key reason why was the standard of living higher comparing to Soviet Union in NSWP countries (except Romania).

Army air defense of other countries

Now we know the army air defense of the Warsaw Pact and the Soviet Union they can be compared to air defense of other countries. The comparison is partially easy because no other country in the world ever had similar army are defense to the Soviet Union. In fact even just the structure and organization cannot be compared in 1:1. For example during the Cold War the "HAWK belt" with later added Patriot batteries was not in such a symbiotic and integrated relation with the ground forces as the army air defense of the Soviet Union and the WPACT. The NATO prepared to a static defense within the limitation of the mechanized mobile warfare.

The goal is to illustrate the main differences in conception and equipment also in the place in structure and organization of western air defense systems. This short section is strongly based of the ***1989 NATO Order of Battle mod8*** and the ***3rd World War in South-West Europe*** documents**.** The latter was made by Hpasp both are in the attachments. For a quick comparison the 2nd German Corps - Ulm, FRG: assigned to CENTAG is a very useful unit. The diagram below does not show every units of the corps only the main combat and support units.



The structure and organization of the II. corps of the Bundeswehr.

The most important units above are the 4th Panzergrenadierdivision (mech. inf.), 8th Gebirgsdivision (mountain inf.), 10th Panzerdivision (tank) and the 9th Luftlandedivision (airmobile) and their support elements. The equipment and personnel of the whole II. Corps is on the right.

The most similar units to Soviet tank and mechanized divisions are the 10th Panzerdivision, the 4th Panzergrenadierdivision and the 9th Luftlandedivision. The difference German units had combat brigades and not combat regiments. The direct air defense of these divisions are the 4th and 10th Flugabwehrregiment (anti-aircraft regiment) equipped with self-propelled Gepard anti-aircraft artillery each with 36x vehicles.

Gepard is similar to Soviet ZSU-23-4 but is has 2x35 mm gun instead 4x23 mm. Besides the SP AAA vehicles these regiments had

Manpower:	130 000
Tanks:	829
	494 Leopard 2A4
	142 Leopard 1A3
	193 Leopard 1A1
IFV:	496 Marder I
APC:	108 M113
ATGM	636
	420 Milan
	120 TOW
	96 Jaguar
Artillery 258	
	60 M110A2
	144 M109A3G
	54 FH-70 (towed)
MLRS	48 LARS
SAM	36 Roland 2
AAA	108 Gepard 1A2
AT helicopter	56 PAH-1
SSM (BM)	6 Lance

216x FIM-43 Redeye[24] MANPAD missiles which were replaced in late '80s with FIM-92A Stinger.

One Soviet mechanized rifle infantry division in the mid '80s had 4x(4+4) ZSU-23-4 + IR SHORAD comparing to the 36x Gepard AAA of the German divisions above. Considering the quantity of AAA vehicles the German divisions were very well armed but they totally lacked the IR/RADAR SHORAD defense (9K31/35 Strela-1/10 on regiment level) and had only MANPADs without good IADS support. Regardless the huge quantity of Gepard AAA vehicles they mostly were good only against helicopters not airplanes because their engagement zones were limited.

The corps level air defense was provided by the 200th Flugabwehrregiment with 36x Roland 2 radar SHORAD vehicles and additional 216 FIM-43 Redeye missiles. The Roland 2 is a similar weapon system to 9K33 Osa. These 36x Roland 2 were dispersed among the three combat divisions but the 9th Luftlandedivision did not get any of them. This means 12x Roland 2 vehicles/division. Above this level was not any missile air defense at all. It was nothing similar to 2K12 Kub (SA-6) or 2K11 Krug (SA-4)

Comparing to the 20x Osa vehicles per Soviet mechanized rifle infantry division the air defense of a German tank or mechanized rifle division was weaker. The main cause of the difference are the longer range of the IR SHORADs and the 9K33 Osa radar SHORAD. The more Gepard AAA does not mean so much.

The Roland is inferior to 9K33 Osa AKM considering the quantity of the missiles ready to launch. It has only two while the Osa AKM has six.[25] The rate of fire is more consistent for the Roland because the reload time is very short. The Roland is able to launch and guide two missiles in a rapid salvo then can happen the quick automatized reload. The Osa can launch quickly six missiles but following the 6th missile a very time consuming manually handled crane reload is required. While the Roland keeps the same fire rate until the last launched missile. In total the Roland 2 has 10 missiles.

(The comparison of Osa and other radar SHORAD systems are in the chapter of 9K33 Osa family.)

We can conclude that ground troops of the FGR's army (Heer) had mobile army air defense – regardless it was called differently – but not only the army had SAMs. Interestingly the Luftwaffe also had air defense units which were assigned to defend air bases. These units had Roland SAMs. In the WPACT 9K33 Osa units never would be used such purpose because air bases were defended by a single S-125M Neva (SA-3). The airbases in West Germany could have such air defense which had more target channel but shorter range missiles. But the defense was provided by the Luftwaffe itself rather than the Heer within the Bundeswehr. The acquired Patriot SAMs in the '80s which were assigned to support the HAWK belt also were in the organization of the Luftwaffe. The case was the same in Italy with Nike Hercules sites. They were operated by the air force not the army.

Comparing to the army air defense of the German 2nd Corps the USA was even weaker. It was restricted on MANPADs, the M48 Chaparral which was roughly equivalent with the Strela-1/10 and the M163 VADS (Vulcan Air Defense System) and later PIVADS AAA systems. The VADS (and PIVADS) was literally M61 Vulcan gun on M113 platform. The VADS did not had any radar even in the '80s the PIVADS had only target distance measuring device without any 360 degree target acquisition capability. Both the PIVADS/VADS and the M48 Chaparral were fed with target data by the AN/MPQ-49 radar which provided the basic IADS

[24] *FIM-43 got Fligerfaust 1 designation in West Germany. It has similar capabilites to Strela-2 (SA-7). It mid '80s it was outdated system comparing to Stinger, Strela-3 (SA-14) or Igla-1 (SA-16).*

[25] https://www.youtube.com/watch?v=bzXV6OoewDM, https://www.youtube.com/watch?v=BZTsf2tc6RM

support for the weapon platforms. [26] Before the arrival of the all aspect IR guided missiles the VADS fired on the incoming targets the M48 on the receding.

Until the '80s the FIM-43 Redeye was the standard MANPAD for US forces as well as the NATO's. Besides AAA, MANPAD and SHORAD did not exist higher level longer range army air defense in the NATO. In theory the HAWK could be act as mobile short (MIM-23A) or medium range SAM (MIM-23B). In Europe regardless of the mobility of the system were deployed to static sites. Only for the USMC can be considered mobile usage of the HAWK. [27]

In the early '80s was fielded the first variant of the Stinger MANPAD the FIM-92A. At the end of the decade is the AN/TWQ-1 Avenger which used the Stinger missile on HMMWV. Also the child of the late '80s the M6 Linebacker[28] the specialized variant of the M2 Bradley IFV also with Stinger missiles. Following the end of Cold War most of the M6 was converted back to conventional IFV. The USA tried to develop and field different kind of army air defense vehicles but they failed. Following the issues incident of the M247 Sergeant York[29] even enthusiasm for developing new self-propelled anti-aircraft system was disappeared. In the conception of the USA the army air defense never was such a high priority because the idea was "USAF will dominate in the quickly". Even today is nothing between the FIM-92 Stinger and the Patriot long range air defense system because of the retirement of the HAWK.

Regardless the NASAMS or NASAMS2 uses American missiles and the whole system can fully mobile USA uses only for defending the Pentagon and the White House: Is only a very few quantity is deployed as anti-terrorist weapon they are not used as way as Russia defend Moscow with S-300/400 units.

In short we can say in the NATO and most of western states the army air defense **roughly meant only SHORAD, AAA and MANPAD defense**. Anything above or besides them rather could be called homeland air defense. The only comparable system to 2K12 Kub was the HAWK which had similar range with MIM-23A missiles. With MIM-23B missile had about the same range 2K11 Krug at medium-low altitude. Only problem NATO never plan to use as such mobile force as WPACT used the mentioned systems and none of them had any armor. Anything similar to S-300V or Buk-M1 never was designed and was put into service. Regardless every elements of the HAWK were mobile the readiness time from stop to launch was nowhere close to Krug or Kub (about 15 min range vs hour or even more). **The size and capability of the Soviet Army air defense was unmatched. The same is the same with today's Russian army air defense. It is simply unique**.

[26] https://www.youtube.com/watch?v=-MUzHaHjixA
[27] http://6thbattalion56thartillery.com/LAAM_Bn_Patches__USMC_.html
[28] https://youtu.be/iaB8PAp6VvQ
[29] https://en.wikipedia.org/wiki/M247_Sergeant_York
https://bit.ly/2PxxaXs
https://youtu.be/lnlI9vSJN0A
https://russellphillips.uk/an-ineffective-system-the-m247-sergeant-york/

Some more words about the air defense of other 3rd World Soviet supported countries. Among is the attachment is the NORTH KOREA HANDBOOK.[30] From page114 (SECTION 4.) we can see that army air defense of DPRK had serious gaps. Regardless the document is 20 years old today the situation is almost the same and of course it is true for the past. The 2K11 Krug never was exported outside the WPACT. Any other country only option was substitute with 2K12 Kvadrat (the export variant outside the WPACT) but the DPRK never acquired it as neither the 9K33 Osa.

Because of these missing systems the backbone of the air defense of the DRPK was based on old AAA guns from 14.5 mm caliber to 100 mm such as ZPU-24, S-60, KS-12, KS-19 and the ZSU-57-6 and MANPADs. In the '80s against second line South Korean (RoK) it may would be useful but today they are totally outdated. Considering the level of electronic warfare and med-hi level altitude targets because of PGMs with optical aiming against fast and high flying targets the combat value of these stone age AAAs are extremely very low.

Because of the Demilitarized Zone (DMZ) the deployed DPRK homeland air defense units partially can cover the troops even in case of an invasion against the RoK. In the mid-late '80s S-75M Volkhov, S-125M Neva and S-200 Vega was acquired in 1987 and 1990. Even comparing to the NSWP states the army air defense is literally non-existent except MANPADs.

Before the radar guided ZSU-23-4 and EO-IR/radar SHORADs and other SAMS only AAA guns were used. As we got lower levels this means smaller caliber AAA guns. The smallest was the 14.5 mm ZPU-2/4 up to the 100 mm KS-19.

Of course the higher level guns had fire control radars but the smaller caliber gun aimed with optics. The quantity and the size of the batteries varied depending on the era and country. The size of the S-60 AAA regiment is usable as a rough estimation for any level.

In Hungary before the 4xZSU-23-4 Shilka per regiment 6x ZSU-57-2 were assigned, before the Strela-1 6xZPU-2 towed gun were used.

30 https://fas.org/nuke/guide/dprk/nkor.pdf

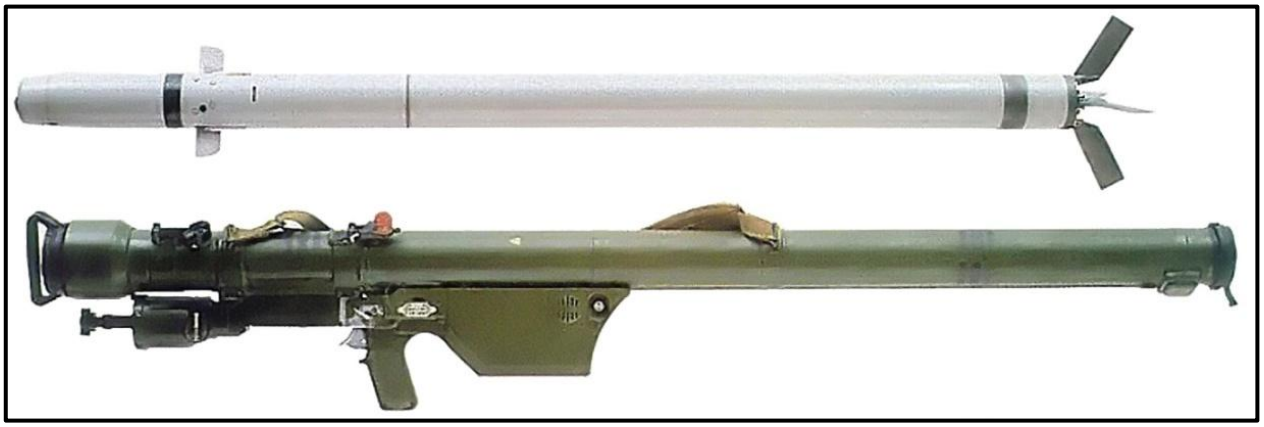
Equipment of the Army Air Defense

Because of the structure and organization this part covers mostly the Soviet and NSWP army air defense with some notes for comparison to US/NATO or other countries.

Below every Soviet/Russian equipment are described which are mentioned previously in the organization section. In each category similar of SHORAD or MANPAD are also described from the US/NATO. In many cases are no equivalent western air defense system because of extent and size of the layered Soviet/Russian army air defense. Using the Soviet sturcure and organization levels the equipment are described from the lowest level MANPADs up to the queen of this category the S-300V/VM.

MANPAD systems

9K32 Strela-2 (SA-7 Grail)



First of its kind in MANPAD category. It was developed in the ’60s. It was fielded in the Soviet Union from 1969 which was quickly followed by the Strela-2M variant.

Following the activation of the power supply can be performed the aim and the launch. The lock of the IR seeker is indicated by buzzer sound. Following the lock is performed the lead aiming then the missile can be launched.

The 9M32 missile is launched from the launcher tube with a small booster engine. As the missile leaves the tube the two forward steering fins unfold as do the four rear stabilizing tail fins either. Then the self-destruct mechanism is armed. It is set to destroy the missile after between 14 and 17 seconds to prevent it hitting the ground if the missile misses the target. The missile is roll stabilized with 15 rotation/min. The missile warhead does not have proximity fuse therefore a direct hit is needed to cause it any damage.

The missile has an uncooled lead sulfide (PbS) passive infra-red frequency modulated seeker head. It detects infrared radiation best at and slightly below 2.8 μm in wavelength. It has a 1.9 degree field of view and can track targets with 9 degrees head direction change per second. The seeker restricted the Strela-2 only to tail engagements (rear aspect). Against helicopters also had very limited effectiveness.

The 9K32 had 3.7 km maximal engagement distance up to 1500 meter altitude the upgraded 9K32M had 4.2 km and 2300 meter respectively. The maximal target speed was 220 and 260 m/s against receding targets. Burnout speed of the 9K32 was 420 m/s and 500 m/s for the 'M' type.

The reaction time of the Strela-2M is about 15 seconds but it strongly depends the situation and the skill of the crew. In case the launcher has mounted on the shoulder, covers removed and sights extended the reaction is about halved.

The Strela-2 family soon saw combat it was used literally every major conflict of the Cold War. Vietnam, Arab-Israeli Wars, in Afghanistan the Mujahideens used the captured weapons against the Soviet forces and well as supply from Iran through Pakistan from Egypt. The results were mixed depending on environment and types of target. Every variants of Strela-2 were very susceptible to flares and the hot brick jammer (such as AN/ALQ-144) also worked very well against them. The whole Warsaw Pact and Soviet friendly 3rd world countries used. Because it was installed even on smaller ships (corvette or smaller boats) got the SA-N-5 designation from Western agencies.

FIM-43 Redeye

It was the contemporary American system of the Strela-2M with a major difference. It had Freon cooled IR seeker from FIM-43C variant but the principle of the guidance was the same. The maneuvering capability was very limited similarly to Strela-2M and had no jamming resistance at all.

Burnout speed of the missile was about 580 m/s, the maximal engagement distance was 4.5 km up to 2700 meters, maximal target speed was 225 m/s. It could be used only against receding targets (rear aspect). The missile did not had proximity fuse. It was just as widespread in the NATO and USA friendly countries as the Strela-2M on the opposite side. About 85 000 were manufactured.

9K34 Strela-3 (SA-14 Gremlin)

It represents the 2nd generation of the Soviet Russian MANPAD development. It was introduced in 1974. The seeker still used the PbS detector technology but it was cooled. The amplitude modulated (AM) guidance principle was discarded to frequency modulated (FM) method. It was less vulnerable to flares and the hot brick /thermal jammer had only limited use against the FM guidance comparing to AM.

The 9K34 had 4.1 km maximal engagement distance up to 2700 meter altitude the maximal target speed was 225 m/s against receding targets, 150 m/s against incoming. Burnout speed was 410 m/s. The missile did not have proximity fuse. It had limited capabilities against helicopters and slow propeller aircraft the Strela-3 was not a really an all aspect missile.

The Strela-3 was not as widespread as the Strela-2. Within the Warsaw Pact only the Soviet Union used the NSWP countries skipped the Strela-3 favor to 9K310 Igla-1 (SA16). It was exported to many 3rd world countries.

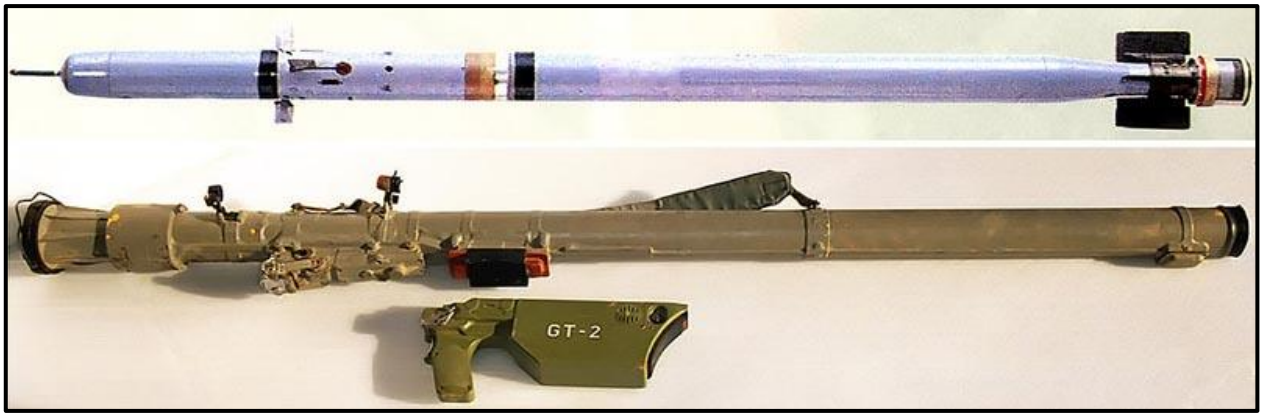
9K310 Igla-1 (SA-16 Gimlet)

It represents the 3rd generation of Soviet MANPAD. It was introduced in 1981. The seeker technology of the Igla-1 was totally different from all of its predecessors. The detector is InSb (indium antimonide) which made possible the lock and launch against incoming targets. It made all aspect missile the 9K310. Besides the new detector it got a new type of FM modulated guidance (Liner Reticle see in the attachment). The new seeker design made very resistant (on paper) against flares and the thermal jammer is totally ineffective against the Igla-1.

The 9K310 has 5.2 km maximal engagement distance up to 3500 meter altitude the maximal target speed against incoming target is 320 m/s for receding target is 360 m/. Burnout speed is 570 m/s. The missile still has only impact fuse.

The Igla-1 was an interim design step because of the development issues of the 9K38 Igla (later called SA-18). In Warsaw Pact East Germany bought 270x launchers and 550x missiles from 1988, Hungary acquired 36 launchers and 432 missiles. Poland and Czechoslovakia did not bought any during the Cold War.

9K38 Igla (SA-18 Grouse)



The 9K38 Igla fulfilled the original design requirements which failed the Igla-1. It was fielded from 1983. It uses the same FM guidance principle as 9K310 missile but it was designed with dual seeker which. This improvement places the missile into totally different category in comparison with any other missiles in any country in that time. (See in more detailed in the attachment.) The system was named after the small spike at the nose of the missile. Igla in Russian means “needle”. The engagement zone of the Igla is identical with Igla-1.

Because of the collapse of the Soviet Union and end of Cold War it was not exported for NSWP countries. The first export order came from Finland which acquired 912 missiles in 1994.

FIM-92 Stinger

The first variant of the Stinger was developed in the late ‘70s and fielded in early ‘80s in the USA. The design of the missile many times were upgraded thanks to the different seekers and their capabilities:

- FIM-92A. It has FM guidance with cooled InSb detector. It was similar to Strela-3 but with better sensitivity because of different detector material and cooling. Even the first Stinger had at least limited all aspect capability. The flare countermeasure resistance was about in similar level to Strela-3. It was fielded from 1981. A total of 15 669 FIM-92A (Basic Stinger) missiles were produced between 1978 and 1987.

- FIM-92B POST. It has rosette scan tracker guidance (see in the attachment) and is dual seeker design similar to Igla (SA-18). The detector uses inSb+CdS materials instead PbS + InSb . It means the detector uses UV and IR spectra ranges and not only two different regions of the infra-red. This design difference in combination with rosette scan tracker guidance makes even more flare resistant the FIM-92B comparing to 9K38 Igla.

  The seeker exploits the low UV reflectance of aircraft compared to the Sun lit sky background. It guides the missile on to the UV 'hole' in the sky represented by the target. The concurrent use of UV and IR allows unambiguous rejection of flares. Another major improvement in Stinger–POST was the incorporation of integrated digital circuits (two microprocessors) to perform the seeker signal processing functions, electronic packaging and performance improvement over the analog circuitry found in Basic Stinger.

  600 FIM-92B (Stinger-POST) missiles were produced between 1983 and 1987

- FIM-92C RMP. It has the same seeker and guidance as the B variant but it uses reprogrammable microprocessor (this is why is got RMP designation). This change enabled the onboard microprocessor to be updated with new software as new information on threats and countermeasures become available. Properly programmed the processor can recognize countermeasures (like flares) and filters them out from the information it sends to the guidance system. Stinger RMP entered production in 1987 until end of 1992 about 30 000 were manufactured.

- FIM-92E Block I PRM. It has the same guidance as FIM-92C. It got software optimization against small IR signature targets such as light helicopters, UAVs and cruise missiles. With laser ring gyroscope the missile is able to perform better the proportional trajectory and avoid fly too high because it can measure the direction of the missile and not only relative position comparing to the target.

All Stinger variants have impact fuse.

Mistral

The Mistral was developed in France in the mid ‘80s, entered in service in the late ‘80s. Despite is described in this section besides the MANPAD systems in fact the Mistral is “half step higher” concerning on engagement range. The demanded longer range leaded to a so large and heavy missile which made impossible to design with shoulder launch capability. The missile needs a deployable stand where it can be installed/mounted. Of course such stand can be installed on different platforms such as armored vehicles, jeeps or ships.

During the design was a crucial factor the minimal drag and as high burnout speed as possible. This demand had strong impact on the shape of the nose design.

Its speed and range places the Mistral closer to IR SHORAD category like Strela-10 but it has even higher burnout speed which is about 800 m/s. (For the most advanced variant is 930 m/s.) The maximal range of the Mistral is about 6 km up to (estimated) 4000 meters in altitude. The maximal overload of the missile is 30G. The missile uses the crossed linear array guidance method. The size of the missile made possible to design with proximity fuse.

The Mistral with certain additional equipment[31] has night engagement capability as some later Russian designed MANPAD and SHROAD systems (9K333 Verba/SA-25).

RBS-70/RBS-90

It is a Swedish surface to air missile which is very unique because of its guidance. The RBS-70 uses laser beam riding. Because of this even the very small size of the missile it needs a guidance station. It is not a fire and forget type weapon comparing IR guided missiles. Because of the necessary equipment the RBS-70 is also not a classical MANPAD it is rather similar to the French Mistral in deployment.

With the guidance station the operator continuously tracks the target. The guidance station emits a narrow laser beams towards to target. The relative position comparing to the different beams generates the error and correction guidance signals for the missile.

The advantage of the guidance it makes immune the system to any type of jamming which works against IR guided missiles because the target is manually tracked. The "brain" of the missile is the operator itself. The disadvantage of the system the high demand of manual skills from the operator especially against maneuvering target. It is far less portable as classical shoulder launched MANPAD systems and of course it is not fire and forget.

The RBS-70NG variant is able to perform auto tracking with small actuators and photo-contrast shape recognition camera. [32]

[31] https://www.mbda-systems.com/product/mpcv/

[32] https://youtu.be/A98FhTbzsko?t=70 , https://www.youtube.com/watch?v=uGqAcYyy4cM

Was a similar system to RBS-70 in the "MANPAD/portable" category the English Blowpipe. Interestingly it had radio command guidance but the missile was manually guided (MCLOS). The conception of the Blowpipe somehow mixed the worst design elements what can be imagined.

Following the launch the missile flew with semi-auto guidance in the center of the field of view of the operator where switched to manual guidance mode. The missile was controlled with a small stick by the operator.

Thanks to the guidance method it was close to impossible to engage high speed cross flying or receding targets. Because of the initial semi-auto phase against low flying helicopters also were hard limitations (missile frequently hit the ground). During the Falkland War both sides used the Blowpipe with very low success rate. English troops launched 95 missiles and only the single MB-339 subsonic trainer was downed while Argentinian forces downed a single Harrier.

What is common in Blowpipe and RBS-70? For the old base variant similar to Blowpipe the chance of success depended almost exclusively of the manual skill of the operator. This makes questionable how would performed in a real combat situation.

The heart and attention of English engineers somehow is very attracted by the manual or semi-manual guidance methods. Even the more advanced Javelin[33] missile still uses semi-manual guidance. The Sea Cat naval SAM also used fully manual guidance with very low missile speed. The Sea Cat was just as "successful" in Falkland was as the Blowpipe was In fact the Sea Cat was literally outdated even from its introduction...

Summarizing chart of portable SAM systems

Type	*Launcher + missile*	*missile*	*Warhead*	*Missile*			*Proximity fuse*
	Weight [kg]			*Target speed incoming/receding [m/s]*	*Engagement distance/alt. [km]/[m][34]*	*burnout speed. [m/s]*	
FIM-43C Redeye	13,3	8,3	1	-/225	3,7/1500	580	No
9K32 Strela-2 (SA-7A Grail)	14,5	9,15	1,17	-/220	4,2/2300	430	No
9K32M Strela-2M (SA-7B Grail)	15	9,8	1,17	-/260	4,5/2500	500	No
9K34 Strela-3 (SA-14 Gremlin)	16	10,3	1,17	150/225	4,1/2700	470	No
FIM-92A Stinger (Basic)	15,7	10,1	1	?/?	4,8/?	?	No
9K310 Igla-1 (SA-16 Gimlet)	18,2	10,8	1,27	320/360	5,2/3700	560	No
9K38 Igla (SA-18 Grouse)	18	10,6	1,27	320/360	5,2/3700	570	From 2004 only from 9K338 Igla-S (SA-24)
FIM-92C Stinger	15,7	10,1	1	?/?			No
Mistral	?	19,7	3	?/?	6 (7)/?	800 (930)	Yes
RBS-70		15	1,1	?/?	8/5000	660	Yes

[33] https://www.youtube.com/watch?v=M78qadYbQNs
The SAM Javelin has nothing to do with the FGM-148 which is a guided anti-tank missile.

[34] *With 0 distance (offset) parameter.*

9K31 Strela-1 (SA-8 Gaskin)

The Strela-1 system used as platform the amphibious BRMD-2 vehicle. The turret azimuth and the missile canister elevation setting were manually controlled with power of the muscle of the operator without any actuator aid.

With the 9M31M missile the maximal engagement range was about 4.2 km up to 3500 meter altitude. Weight of the missile was 32 kg the warhead weight was only 2.6 kg. The missile had proximity fuse in contrary to contemporary 9K32 Strela-1 MANPAD.

The missile used photo contrast detector for guidance instead of infra-red wavelength. It was decided to use the visible part of the spectrum (0.4-0.65 μm) because in that time it was the only way to provide all aspect engagement capability. The IR sensors at the time was not able to provide such feature. The photo contrast was usable against targets visible on a background of clear sky away from the horizon. With the contemporary Strela-2 MANPAD locking on incoming target was impossible but the cloud and the horizon meant less restrictions. With Strela-2 was possible engaging aircraft only in pursuit mainly after it performed its combat missions.

The missile was roll stabilized by its rollerons. To spin those up during launch an elegant method was used. On the rollerons a rope was spooled up it was connected to the launch container. During launch the rope was unrolled during missile acceleration and spun up. Missile had no inbuilt self-destruct system it simply safetied the warhead after 13-16 second of flight. Each vehicle had four missiles ready to launch on the turret. Two additional missiles were carried on the side of the chassis.

The upgraded Strela-1M was fielded in December of 1970. In comparison with the autonomous Strela-1, the Strela-1M platoon was designed to work together with a ZSU-23-4 Shilka platoon directed by the PU-12M (or other) mobile air defense command post.

Strela-1M was widely used in the Warsaw Pact and in Soviet friendly 3rd world countries either. The disappearance of the Strela-1M happened very quickly because of the crystallization of the propellant in the solid rocket engine which made unsafe and hazardous to use further the missiles. After about (or less than) 20 years of service disappeared from the inventories from all of its operators.

With today's standards the capability of the Strela-1M was very limited. Its design was quite crude and basic with human powered turret, no radar, no target distance meter/rangefinder. Regardless all of its design and operational flaws the Strela-1 left the mark on the evolution of the SHORAD IR SAMs. The base conception still lives in later designed SHORAD vehicles but in a much more advanced way.

9K35 Strela-10M (SA-13 Gropher)

The work on the creation of self-propelled air defense system Strela-10 began under the Decision of the Central Committee of the CPSU and the USSR Council of 24/07/1969.

Despite the in the same time development of anti-aircraft gun-missile system (later called 2K22 Tunguska) was ongoing, the creation of a simple cheap SAM, based on the further development of the complex type Strela-1 was considered appropriate from an economic point of view. During 1974 the system was presented for state trials but failed. It was only accepted into service in 16 March 1976.

The 9K35 Strela-10M was designed to replace the 9K31 Strela-1 with 1:1 quantity ratio. The amphibious tracked MT-LB chassis replaced the wheeled BRDM-2. Comparing to Strela-1 the missile had an additional selectable IR mode but it was not dual seeker missile. Before the launch the operator had to select between the photo contrast or the IR guidance.

The photo contrast channel (also used by the Strela-1M) did not require cooling and could be used against both incoming receding targets but was not protected against natural optical interference (heavy clouds with strong contrast, horizon line). The infra channel required prior cooling and could be used only against receding targets but it was effective against natural optical interference. Because the 9M37 missile used PbS detector with IR guidance against incoming target was not possible to perform a lock.

The parabolic antenna between the missile canisters is the target distance meter/rangefinder radar. While the Strela-1 relied solely on human eye to determining the distance of target (position relative to engagement zone) for the Strela-10M this additional equipment was provided. The millimeter wave rangefinder radar provided the firing zone and lead angle calculation.

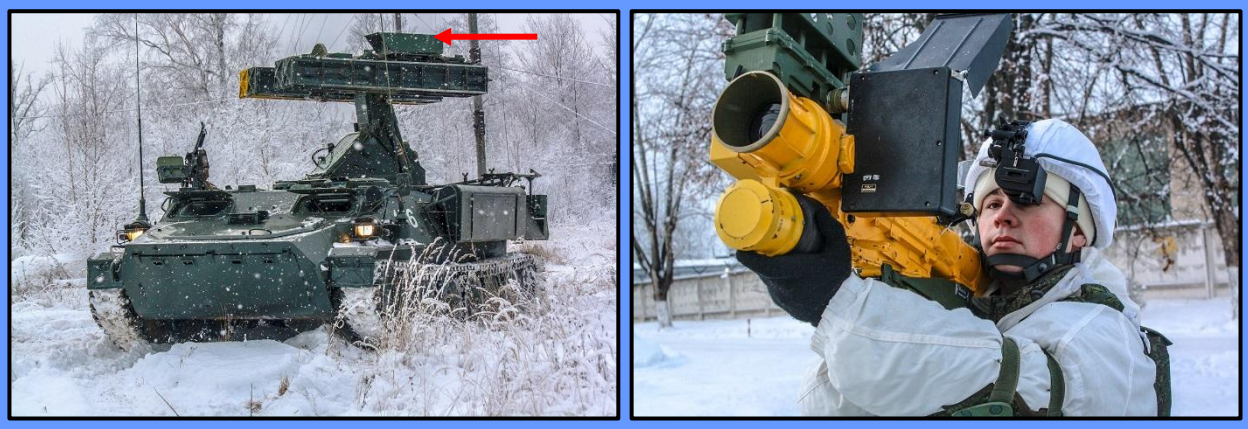
The 9M37 missile is heavier comparing to 9M31M (40 vs. 32 kg) and got a larger warhead (3 kg vs. 2.6 kg). The missile is equipped with proximity fuse. The maximal engagement distance is 5 km up to 3500 m meter altitude. Maximal target speed against incoming targets 415 m/s, against receding targets 310 m/s.

The vehicle carries four missiles ready to launch and four more inside for reload. It is quite an interesting in its design that carried missile quantity remained only four on the turret. For comparison from the 9K33 Osa system was expected to double the carried quantity from 4x to 8x but only 6x was doable for the AKM. The Strela-10M did not make any improvement comparing to the predecessor system only the reloaded quantity is increased and put inside the vehicle.

As well as other SAM system the Strela-10 got many upgrades since the introduction. While the 9M37M had only IR/photo contrast guidance with 9E47 type guidance section it was replaced with the 9M333 variant which was applied on R-27T/ET (AA-10B/D Alamo) missiles either. The missile got laser proximity fuse against targets with small radar cross section.

The latest Strela-10M (M4) variant is equipped with night vision camera. In case target coordinates are available via digital datalink target can be found and tracked. Without datalink and radar support night engagement capability is not possible.

In fact with none of the IR guided MANPAD or SHORAD or similar portable system has night engagement capability without datalink and radar support because of the optical tracking requirement. Even an operator has night vision google or camera to spot an aircraft the FOV is very narrow only some degree wide because of the magnification. Only by chance is possible to find/spot a target with such a small FOV, The high magnification is required for the visual identification as well as performing the lock and the launch. Some of the SHORAD systems with laser beam riding guidance even following the launch is required **the continuous target tracking** comparing to 'fire and forget' IR guided missiles.



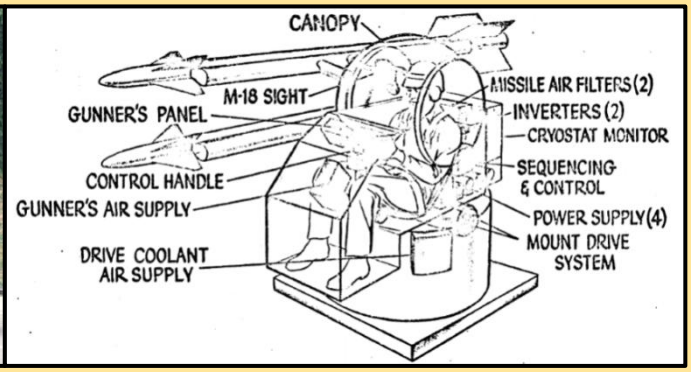
On the image above left is the Strela-10MN with additional NVG camera above the canisters. Above right is an 9K333 Verba MANPAD with additional IADS and night vision equipment.

With datalink support the turret of the SHORAD vehicles can be turned automatically and quickly can be found and tracked the target to performing lock and launch.

Today even with MANPAD is possible to engage target such way because they also can have NVG support with the necessary displayed data. Of course only a very few, only the most advanced systems are capable to do this. It is not surprising such systems are mostly or only exist in Russia thanks to the heritage of Cold War development and layered army air defense conception.

On the video below is a upgraded 9K35 variant with night vision camera.
https://youtu.be/8ZJVRBRRQVk

The closest system to Strela-1/10 in the NATO was the US designed and manufactured M48 Chaparral[35] but rather developing dedicated missile it used AIM-9 Sidewinder family as a base. The M48 originally was intended only an interim solution until a much more advanced and capable SHORAD system will be available. That would be the failed Mauler. Because of the fail of Mauler the M48 eventually remained in service for almost 30 (!) years regardless it was not a well-respected system by of its operators. Because of the need and being "interim solution" the Chaparral many times was upgraded.



The first missile based on AIM-9D which lacked the all aspect capability because of the PbS detector and had only the most primitive AM guidance. The last MIM-72G missile[36] in late '80s got the most advanced seeker of its time the same what the FIM-92C Stinger variant had while the best USAF AIM-9M variant still had only FM guidance with much more primitive IRCCM solutions.

Comparing to 9K31 Strela-1 the turret design was more advanced because it was motor driven and not human powered. But on the other hand according to former operators of the system the turret was very uncomfortable for long work even with the aided rotation and aim.

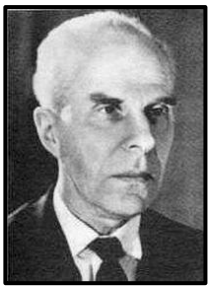
The engagement zone – especially before the longer range AIM-9L/M missile variants – was only 4 km similar to Strela-1 but even with more advanced missiles the range was only 5 km up to 3000 meter altitude.

(See the engagement envelope diagram at the end part of the chapter about 9K33 Osa. (SA-8.)

35 https://www.youtube.com/watch?v=lHmKDKpsLIk , https://goo.gl/CucnR8

36 https://wiki.scramble.nl/index.php/Raytheon_AIM-9_Sidewinder#Related_variants

ZSU-23-4 Shilka



Shilka (is named for a river in Eastern Russia) was the first self-contained, mobile, radar-guided AAA (anti-aircraft artillery) system. It was designed by OKB-40 under the leadership of N.A. Astov. It was fully NBC (Nuclear Biological Chemical) protected by a filtered over-pressurization system. The Soviet Union fielded the first version in 1964. The Shilka was constantly improved during its lifetime resulting in the ZSU-23-4V, V1, M1, M2 and M3 variants.

It was widely exported and participated in several Cold War conflicts which made one of the most iconic weapon system of the Cold War, especially because it was so successful in the 4th Arab-Israeli (Yom Kippur) was in 1973.

In 1973 the strike fighters generally employed their weapons at low level because guns, unguided rockets and bombs achieved the necessary accuracy only at very close range at low level. The effective range of the 23 mm gun the was smaller than the gun of the predecessor ZSU-57-2 – only 2500 meters – but the accuracy and efficiency of the new AAA system totally outclassed the previous generation.

This higher combat capability was supported by the radar target tracking, the ballistic "computer" (mechanical fire solution calculator) and the very high rate of fire. The cumulative fire rate of the 4x23 mm gun was 3400 round/min. The total ammo capacity of the vehicle is 2000 round. In theory the full load can be fired in a very long continuous salvo. In reality after 120-150 shots about 10 second cooling was optimal. The Shilka was capable of firing on the move. The chassis of the ZSU-23-4 is the same as the PT-76 amphibious recon tank but the ZSU-23 is not amphibious.

The fire control radar operates on 2 cm wavelength it can detect a MiG-21 size target from about 13 km. The maximal possible target tracking range is 20 km. The fire control system is able to perform target acquisition but only in sector search mode and with very limited capability because of the 2 degree wide pencil beam. During target acquisition the pencil beam of the antenna mechanically scans a degree sector vertically (elevation). The system has the best efficiency in case the gets coordinates from the 9S482 BTR-60 PU-12 mobile air defense command post via radio (or from any other command post). The PU-12 gets the coordinates from higher level radars via digital datalink.

Shilka has the following firing modes:[37]

1. Full Automatic Tracking of an aerial target with the 1RL33 RPK-2 (Gun Dish) radar in angle and range. Firing solution is provided by the 1A7 SRP mechanical fire solution calculator.
2. Optical angle tracking of an aerial target, while the 1RL33 RPK-2 (Gun Dish) radar is measuring the target range only. (used in case of angle jamming conditions) Firing solution is provided by the 1A7 SRP mechanical fire solution calculator.
3. ZU (memory) mode. In case of losing the target, the radar is automatically following its predicted path.

[37] http://www.mediafire.com/download/y5s92qmc18jdkms/SAMSim_docs_150803.rar

4. Optical aiming used against an aerial target. This is only a backup mode in case of malfunction of either the 1RL33 RPK-2 (Gun Dish) radar or the 1A7 SRP mechanical fire solution calculator or GAG (gyroscope) unit.

5. Fire against ground targets.

ammo flight time	Distance	Velocity	Drop	Dispersion	Penetration
s	m	m/s	m	m	mm
0s	0	980	0 m	0	38
0.2	**200**	**860**	**0.2**	**0.4**	**32**
0.6	**500**	**700**	**2**	**1.2**	**25**
1.4	**1000**	**520**	**10**	**2.8**	**19**
2.5	**1500**	**400**	**30**	**5**	**16**
4.17	**2100**	**310**	**85**	**8**	**14**
5.5	**2500**	**280**	**150**	**11**	**14**
11	3800	210	600	22	13

The 23 mm Ammunition Ballistics calculated by the 1A7 SRP

Maximal target speed of the Shilka is 450 m/s, maximal target distance is 2.5 km up to 1500 meter altitude. In Afghanistan a modified version of the ZSU-23-4 was used because of its very high turret elevation which make possible to provide fire support in mountainous environment where tanks and APC and IFV vehicles were unable to do that. Below are videos and about the system:

https://youtu.be/_mCbGwz_d34
https://youtu.be/HaYCjfvHIsQ
https://youtu.be/CuWoVPbPkHQ

The last video is slightly inaccurate about the crew workstations and role. From the left to right are the following crew member: Commander, angle officer, range officer. The radio is handled by the commander and both the commander and the range officer is able to fire.

Not only the Soviet Union and other Warsaw Pact countries had self-propelled AAA system. The NATO also used them in larger numbers. Such system is the German Flakpanzer Gepard equipped with 2x35 mm cannons, the French AMX-13 DCA 30[38] which based on the chassis of the AMX-13 tank or the American M163 PIVADS which used the much smaller 20 mm caliber M61 Vulcan gun much higher fire rate but with less range. The conception of the South Korean K-30 BIHO is also similar what it makes unique its amphibious capability.

Above left is the Flakpanzer Gepard on right is the AMX-13 DCA 30.

38 *http://www.tanks-encyclopedia.com/coldwar/France/AMX-13-DCA/*

2K22M Tunguska (SA-19 Grison)

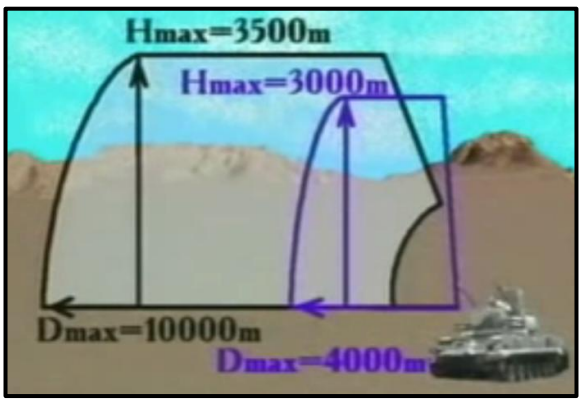
The work on development the successor of the Shilka, 9K33 Strela-1 (SA-9) and 9K35 Strela-10 (SA-13) systems started in 1970. It was not an easy birth.[39] When the project started the guided anti-tank guided missiles (ATGM) barely existed but they strongly changed the course of the development.

The chassis of new SAM is the GM 352 type. Amphibious capability was not demanded while both predecessor of the 2K22 were such kind of vehicle on different base.

The new combined SAM + AAA system had to deal with the A-10A Thunderbolt II attack airplane (with AGM-65 Maverick air to ground missile) as well as helicopters equipped with ATGMs. It the mid '70s BGM-71 TOW (on AH-1 Cobra) and the European HOT I missiles (on Gazelle, Bo-105) were the main threats with about 4 km maximal engagement range. Because of the AH-64A Apache with AGM-114 Hellfire missile the range of the threat increased to 8 km. The AH-64A was even more dangerous because it has night combat capability. The ZSU-23-4 did not have enough range even against the TOW and HOT I capable helicopters while the Strela-1/10 did not had night time capability. This was the base of the demand for a new system.

The 2K22M intended to replace with more than one air defense vehicle but with smaller quantity. The Soviet regiments (both mechanized or armored) had 4+4 Strela-1/10 + ZSU-23-4 Shilka but only 6x Tunguska per regiment was planned as replacement.

The design of the 2K22M Tunguska inherited from both the AAA and SAM systems either. Target tracking is possible with radar and TV camera (optical channel) either. The vehicle has its own target acquisition radar which makes it similar to 9K33 Osa. The target acquisition radar has 18 km nominal detection range with minimal 15 m altitude search capability. Neither of the predecessor system had autonomous target acquisition capability even the Strela-10M had only rangefinder radar. The sector search capability of the ZSU-23-4 was seriously limited comparing to the 360 degree scan dedicated radar. As usual the best option to rely on digital data link when target coordinates are supplied by other radars and IADS elements. In this case the target acquisition can remain silent the position of the 2K22M is remain hidden.



Regardless the guided missiles the Tunguska kept the anti-aircraft guns either. While the Shilka had 4x23 mm 2A7 type guns the Tunguska got a pair of 30 mm 2A38 type guns. Thanks to the increased caliber not only the effective range but the destruction power of the gun increased comparing to the Shilka. Maximal range is 4 km up to 3000 meter altitude with maximal 2 km distance (offset) parameter. Maximal target speed is 500 m/s. [40]

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[39] *There is long document about the development among the attachments. The original document is in Russian the translation is just a very crude one by the Google Translator. Both are included.*

[40] https://youtu.be/KUc8iJ0QvEs?t=1m31s

The main armament of the Tunguska is the eight 9M311M or 9M311-M1 type missiles with radio control guidance (RCG). Maximal range is 10 km (with 9M311M is only 8 km) up to 3500 meter altitude. With maximal 4 km distance (offset) parameter maximal target speed is 600 m/s.[41] During movement is not possible guide and launch missile only the guns can be used. Similarly to 9K33 Osa the 2K22M can perform only three point guidance. Both the target and the missile has to be in the beam of the SCC antenna.

The design of the missile is different from any previous Soviet SAM system. The missile has two stages but second stage is just a "dart" it does not have rocket engine. The burnout speed of the missile is about 900 m/s. The first stage is separated just 2 seconds from the launch. Launch weight of the 9M311M is 57 kg, warhead weight is 9 kg.

The 9M311 missile.

The AH-64A Apache made urgent the appearance of the Tunguska but even need until end of the Cold War only a handful were manufactured just the 2K22 initial variant. The development of the mass produced 2K22M was finished only after the end of Cold War. Even in 2017 the Tunguska did not fully replaced the Strela-10M family.

Regardless the 2K22M did not fully replace the Strela-10M family there is another possible successor system the Sosna.[42] The basic principle of the Sosna is different from both IR guided missiles and the Tunguska. The Sosna is similar to the Sweden RBS-70 which uses laser beam riding guidance while Tunguska uses RCG.

In the chapter about S-300/400 is mentioned the 96K6 Pantsir (SA-22 Greyhound) but the system itself is not described there. Regardless the Pantsir is a self-propelled is not an army air defense system because it does not have ABC protection and armor. It can be called as upscaled and upgraded version of the 2K22M. The Pantsir has a tracked, self-propelled ABC protected variant but so far nobody has bought any of them not even Russia (on the image bleow right).

The Pantsir-S1 (above left) is designed to protect S-300/400 missile batteries because their fire/launch arc is limited to 105/90 degrees (PT-PMU1/PMU2-S400) which make possible to attack and saturate the defense if attacking from multiple directions is possible. The role of the S-300/400 is area denial and long rage engagement which makes expensive the large missiles.

41 https://youtu.be/KUc8iJ0QvEs?t=1m31s

42 https://www.youtube.com/watch?v=fQ4enjehMB8 , https://goo.gl/suF4s4

Many times is technically impossible to ensure the self-defense capability ofS-300/400 batteries and even it would be it does not mean it is economically viable. The incoming ARMs, cruise missiles or smaller bombs many times can be detected from less range. Because of their speed is enough defeat them from much smaller distance than range of S-300/400 systems. This conception leaded to development of the Pantsir. One S-300/400 missile battery is (or will be) protected by 6x Pantsir-S1.

The 57E6 missile is radio command guided similar to 9M311 but the comparing to single target channel of the 2K22M the Pantsir-S1 has four thanks to the phased array radar on the vehicle. The radar of the Pantsir tracks not only the target but as well as the missile similar to S-300. It is possible to guide with radar three missiles on three targets and the usual optical tracking makes possible to track one more target.

The missile is the enlarged variant of the 9M311 missile of the 2K22M. The weight is increased to 74 kg, burnout speed is 1300 m/s. The maximal engagement range increased to 20 km maximal target altitude can be 5-15 km depending on the type of the target. The carried missile capacity increased from 8 to 12 comparing to 2K22M.

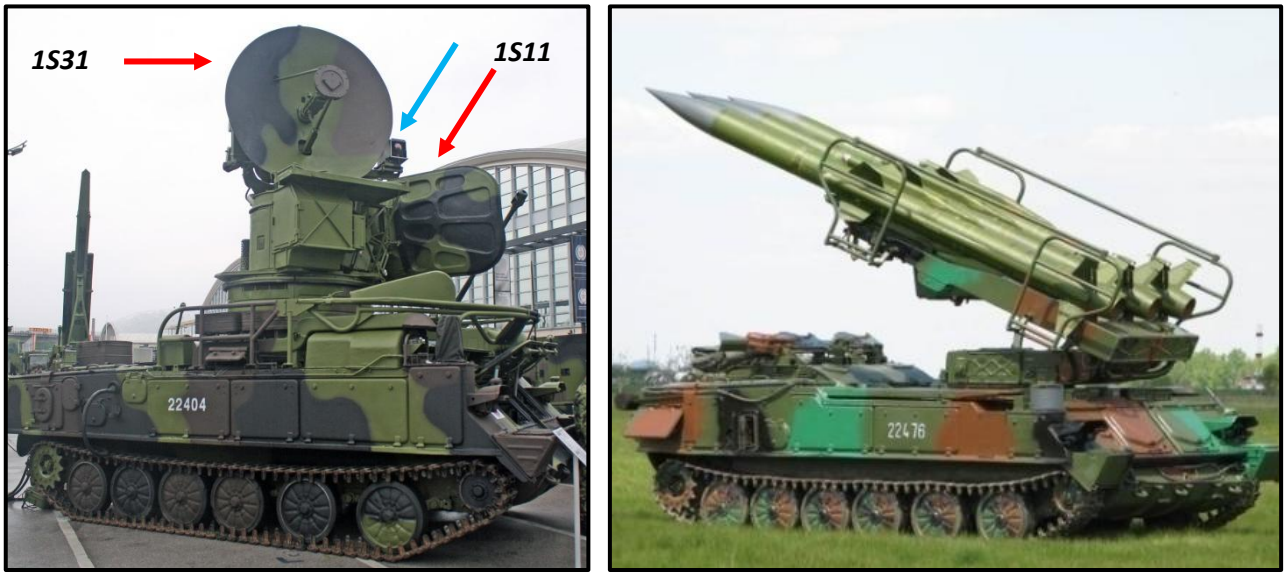
The 57E6 missile.[43]

1 – proximity fuse, 2 – contact fuse 3 – warhead 4 – explosive filler, 5 – canard actuators, 6 – electronics module, 7 – gyro package, 8 – electric generator, 9 – RF transponder beacon, 10 – optical beacon

Below are videos and about the system:
https://youtu.be/jEfsSu1-Z-Y
https://youtu.be/GQtIANpswgE

[43] *http://www.ausairpower.net/APA-96K6-Pantsir-2K22-Tunguska.html*

2K12 Kub/Kvadrat (SA-6 Gainful)



The two main equipment of the 2K12 Kub (SA-6 Gainful) system both are self-propelled. The 1S91 SURN radar station and the 2P25 self-propelled missile launcher.

The 2K12 Kub was the division level SAM system of the Soviet armored divisions during the Cold War. Despite its role many NSWP mechanized divisions had Kub regiments instead 9K33 Osa (SA-8) regiments because of the delayed development of the Osa. Even after export of Osa most of divisions equipped with Kub never were rearmed to 9K33 Osa. (Hungary never acquired any Osa.)

Many NSWP countries used the Kub as an interim solution as army level air defense instead 2K11 Krug (SA-4 Ganef). Hungary replaced the Kub with Krug. Poland and Czechoslovakia even at the end of Cold War used on army level the Kub while at front level they operated full Krug brigades. (In Hungary the Soviet forces provided the front level air defense with Krug.)

The 2K12 is one of the most iconic Cold War SAM system thanks to its performance in the 4th Arab-Israeli (Yom Kippur) war where made a very successful debut in 1973. Export variants outside of the WPACT got a different (degraded) export variant which was called the 2K12 Kvadrat.

The Kub was the first really short range[44] fully mobile SAM system. All elements of the battery was self-propelled on tracked chassis. From march the full readiness state could be reached within 5 minutes with trained crew.

The structure of the Kub system is similar to the homeland SAM systems but are some technical differences because the 2K12 had to be designed fully mobile. One Kub regiment is built up from one commanding battery and 5x missile batteries. For each missile battery was designed the 360 degree target acquisition capability as well as for SA-2/3 (S-75/S-125) batteries.

The very long range target acquisition radar was available only for the commanding battery but this was designed later. The commanding battery had the P-40 complex with the 1RL128 target acquisition radar as well and the PRV-16 height finder radar. The 9S416 KBU fire control cabin forwards the target coordinates to the missile batteries using data link. (Sometimes the Kub command battery got P-15/18/19 radar instead of P-40 complex.)

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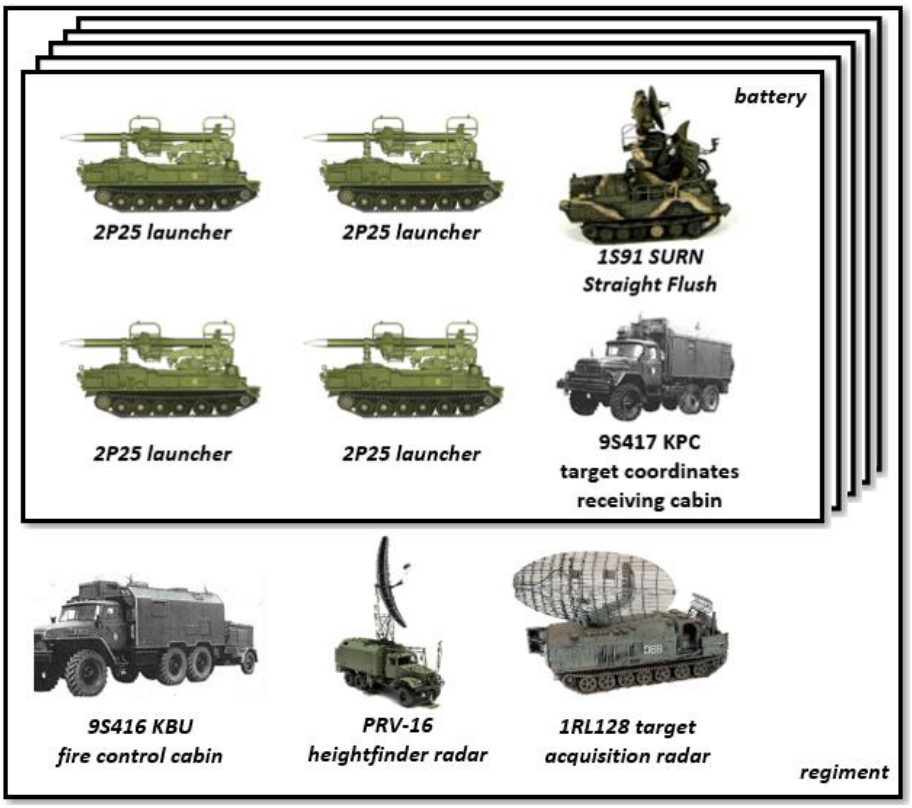
[44] *Some sources calls it medium range. It is on edge of the medium and short range category. Many sources use the medium denomination above 25 km range.*

The 1S91 radar station (SURN) of the missile battery is equipped with two antenna systems. One of them is the 1S11 target acquisition radar another is the 1S31 continuous wave target tracking/illuminator radar. The detection range of 1S11 against MiG-21 size targets is about 70 km the 1S31 has only about 40 km range.



The missile uses SARH guidance but optical target tracking is also available similarly to SA-2/3 family. This optical tracking capability has function from 3M9M3 missile variant because of the SARH guidance. (The SA-2/3 used RCG). On the image on the previous page the blue arrow shows the camera on the SURN radar station.

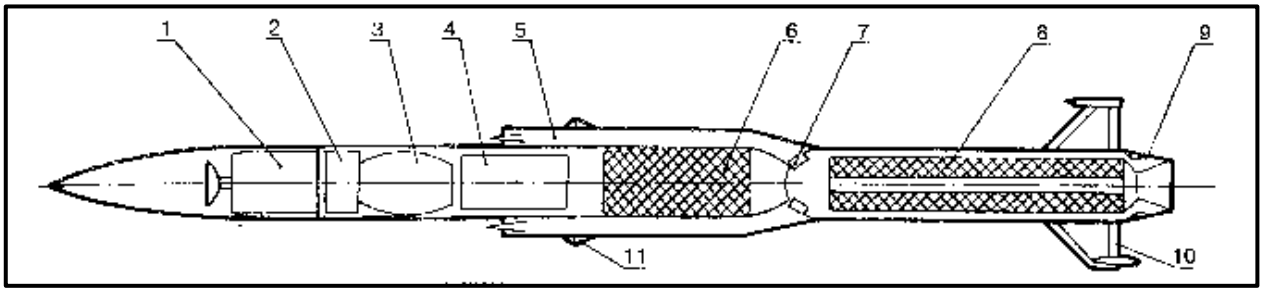
Each missile battery has 4x 2P25 launchers each with 3x missiles and the 1S91 radar station (SURN). Because of the SARH guidance the system has only a single target channel but any missiles can be launched against a single target similarly to the S-200 Vega (SA-5 Gammon). The tracking method of the Kub was similar was designed to MiG-23. Using the coordinates from the commanding post or the 1S11 radar the 1S31 was set to the direction of the target then started the CW target illumination before the missile launch.

The engagement range of the 2K12 Kub was much smaller than the contemporary S-75M Volkhov (SA-2E) and even the S-125M Neva was superior in term of maximal engagement altitude. Considering the zone against tactical targets the maximal altitude difference had no impact in real tactical situations. Because both the S-125M and 2K12 are designed at the ‘60s they are compared regardless the first is a PVO system.

The typical targets of the Kub during the Cold War rarely flew higher than 6 km and only very rarely even more higher. In the ‘70s and even in the ‘80s precision guided munitions (PGM) were not widely used. Later the first of PGMs could be used only at low and medium altitude but almost every airplanes used unguided bombs and rockets. During the Cold War only a very few weapons on tactical fighters and strike fighters could be employed out the engagement zone of the 2K12. The only exception were literally the ARMs (such

as AGM-78 or AGM-88). The AGM-45 had short range even it was launched at medium altitude (and could be use only the main lobe of the radars for guidance).

Considering the quick relocation capability, the continuous wave (CW) illumination with SARH guidance and better missile maneuverability the Kub/Kvadrat was superior comparing even to short range S-125M Neva Before the engine burnout the turning capability of the missile was 15G which made a very serious threat any fighter in that time especially if the fighter still carried heavy stores.

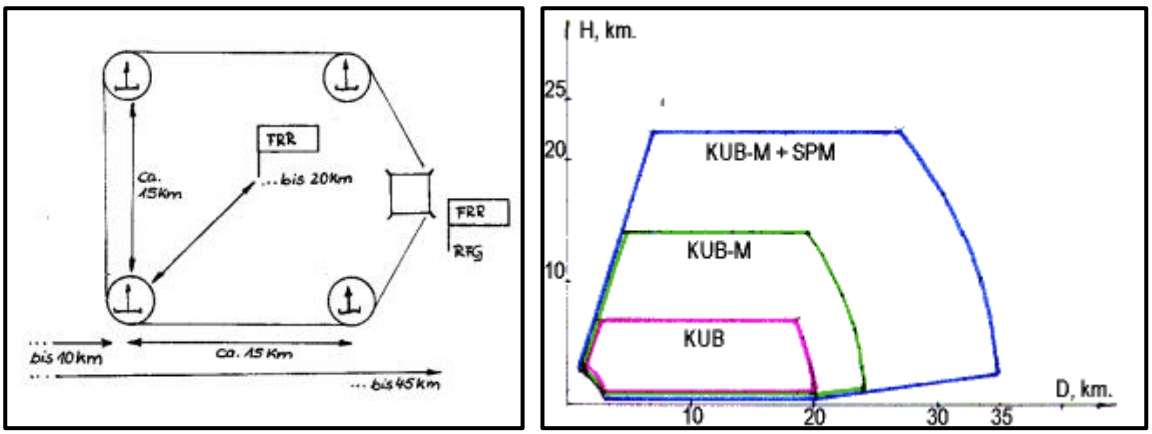


1 1SB4M CW monopulse semi-active homing seeker with Doppler closure rate capability
2 3E27 CW radio two channel proximity fuse (30 m nominal radius)
3 3N12 57 kg blast-fragmentation warhead
4 1SB6M Autopilot
5 Ramjet intake ducts
6 9D16K sustainer solid gas generator charge (67 kg LK-6TM reducing propellant)
7 Frangible seals
8 Boost stage solid propellant charge (172 kg VIK-2 propellant)
9 Exhaust nozzle
10 Cruciform tailfins
11 Cruciform wing

The launch weight of the 3M9 missile is 600 kg (comparing to VP-601P 5V27 missile of the Neva which was 952 kg) the propellant weight is only 172+67 kg (for 5V27 was 280+151 kg). The separation of propellant weight is because of the design of the engines of the missile. While the 5V27 missile had two real stages with jettisoned solid booster the Kub has a much more advanced missile design.

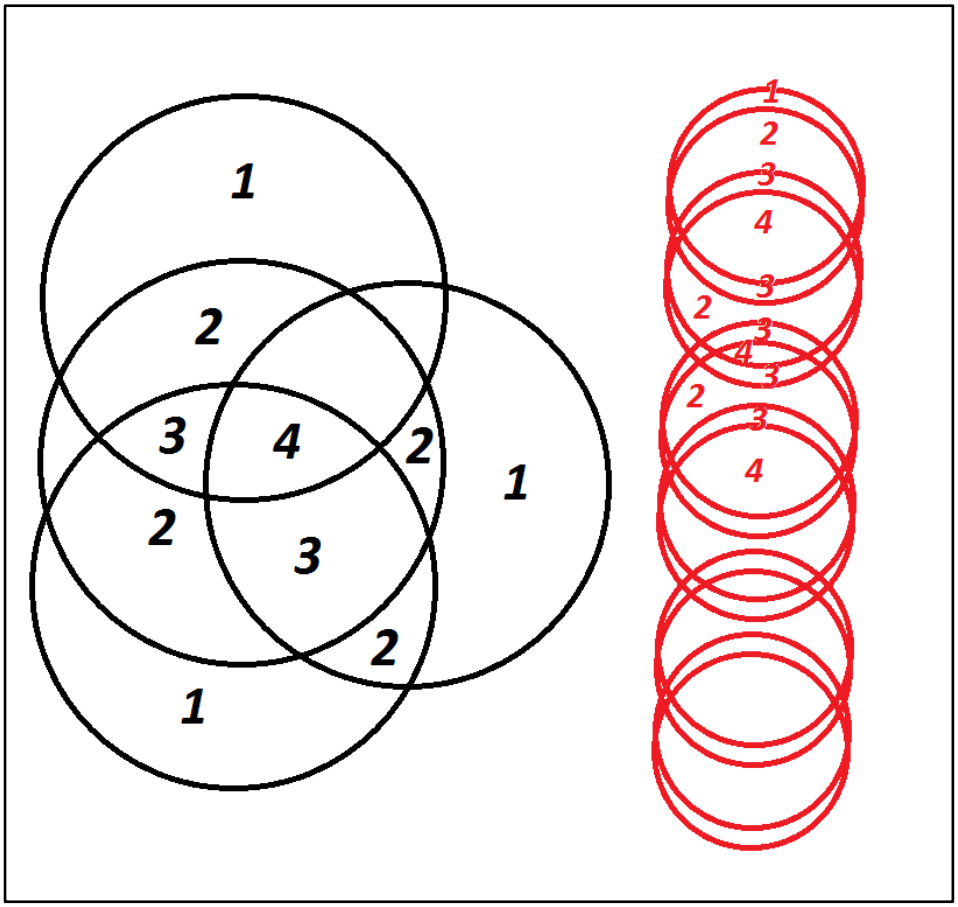
The 3M9 missile was designed with separated engine chambers without having a jettisoned first stage. The booster engine (“8” on the drawing above) runs about 3-6 seconds and accelerates the missile up to 470 m/s (M1.5). Then starts the sustainer ramjet engine (“6” on the drawing above) which is also used solid propellant but in a different way as conventional missiles. **It was the first ramjet engine designed SAM in the world** which uses the oxygen of the atmosphere. Using this design approach it was possible to reach about 20 second of engine operation time for the second thrust phase only with 67 kg propellant (about half of the 5V27). The top speed of the missile was about 900 m/s (M2.8). The weight of the warhead is 57 kg, maximal target speed is 600 m/s.

Besides of the many advantages of the ramjet engine it carries some disadvantages. As the altitude increases the oxygen content in the atmosphere decreases therefore the thrust of the engine also decreases. Very likely this is the limiting factor in altitude for the engagement zone. Because of lack of PGM in that time this factor was so negligible that it could not be called a real disadvantage. The smaller, lighter and more compact missile has more good impact on capabilities then disadvantages. The engagement zone of Kub-M means almost an area denial capability against aircraft with unguided bombs and rockets.



Above left is one of the used deployment method with four missile batteries and one commanding battery. (Most of the East Germany regiments had only four missile batteries instead five.) Above right is the engagement zone of the different variants of the Kub with 0 km offset distance parameter. The Kub-M variant engagement zone is the definitive.

Below is on a diagram we can see the firepower of a single Kub regiment with four target channels assuming one of the battery is in relocation. Even if one battery is in relocation the rest of the batteries can have large overlapping engagement zones. The total available target channel of a 2K12 Kub regiment was considerably fewer (5x vs 20x) comparing to a full Osa (SA-8) regiment but the defended area was larger and in some cases the "density" of target channels was higher.



Idealized comparison of the available target channel quantity of the Kub and Osa systems. 4 of 5 of Kub batteries are in deployed state 12 of 20 Osa vehicles of a full division are displayed. We can see depending on terrain, the position of the SAMs (Osa vehicles are directly attached to fighting battalions) sometimes can be achieved better coverage with Kub sometimes with Osa. Because armored divisions got the Kub and mechanized infantry the Osa at least for Soviet armies both have to be considered.

With the 3M9M3 missile the Kub became capable to launch a missile without tracking and locking target with the 1S31 CW illuminator. Based on the coordinates forwarded by P-40 complex or other higher level target acquisition radar with optical tracking the missile can be launched toward to a pre-calculated impact point. Only in terminal phase has to be used the CW illumination. Using the feature it is possible to reduce the available time for counteractions especially if the launch of the missile cannot be detected visually. For example can be a cloud layer between the target and the SAM. Very likely this is how was downed the F-16 of Scott O'Grady in 1995 by the Serbian air defense.

On the launched missile are visible the closed inlets of the sustainer engine with white colored plastic caps. They are removed following the ignition of the larger engine.

Considering jam resistance the 2K12 Kub was huge step forward comparing to all previous RCG SAM systems (S-75/125) because of the CW illumination and the monopulse seeker. (HAWK used the same guidance principle as Kub.)

In 1973 the Israeli Air Force did not try to jam the SURN because of the fear this move just making more easier to track jamming targets. The CW + monopulse made immune the Kub against the angle deception jamming which was usable against RCG SAMs without monopulse antennas (S-75/125). Of course the 1S11 target acquisition radar or the P-40 complex could be jammed made it harder to provide target coordinates for the missile batteries.

The threat of the SA-6 could not be reduced as way and as level as was possible against older type of SAMs. The first real solution besides the VGPO type of jamming was the ALE-50 towed decoy but only after the Cold War. The ALE-50 decoy made its debut in 1999 during the Allied Force where it saved many airplanes.

Regardless the Kvadrat was very successful in Yom Kippur war in later conflicts gained much less trophies and sustained heavy casualties especially in 4th Arab-Israeli war. But it happened not because of the design of the system. The problem was as way as they were used by Arabian forces.

After the Cold War some of the former WPACT members upgraded further their SA-6 but the level of upgrade was not the same for every operators. The upgraded Hungarian Kub batteries are very likely the most advanced variants of the SA-6. Thanks to the upgrade they can be integrated the IADS of NATO systems such as HAWK or Patriot. The missile battery can acquire target coordinates from both of US made systems or any other radars in the digital data link system. The old camera is replaced with a more advanced with night vision camera which makes possible tracking capability even at night. The CW illumination in terminal phase can be used even better than previously and not only at daytime.

Regardless the Kub system has older roots than 50 years it is still used even today (2019).

Hungary acquired the first SA-6 in 1975 and initially used as army level air defense unit (in Keszthely). From 1981 it was replaced with 2K11 Krug therefore the Kub batteries were sent their original organization level to the divisions in first echelons. Hungary acquired 5x Kub-M1 and 6x Kub-2 batteries. Later every batteries were upgraded to M3 configuration.

Both Soviet armored divisions in Hungary were equipped with 2K12 Kub in Szentkirályszabadja and Komárom locations.

As usual finally below are some videos and images about the system
http://www.ausairpower.net/APA-2K12-Kvadrat.html
https://www.youtube.com/watch?v=Dmgn3RWXQUk
https://www.youtube.com/watch?v=y1qCOfQjAQU
https://www.youtube.com/watch?v=OdDAtHumZeg

Below is the 2K12 in strongly upgraded configuration.

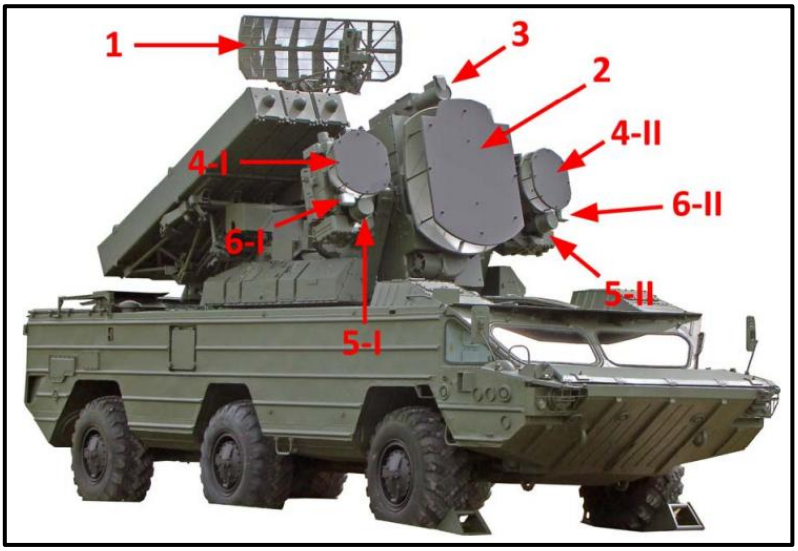
https://www.youtube.com/watch?v=5kLBEhXHU24

9K33 Osa (SA-8 Gecko)

The 9K33 Osa was designed with one of the most complicated mechanically scanned radar system ever. It is similar to 2K11 Krug (SA-4) but despite its smaller engagement range it was even more complex in some aspects than the SA-4.

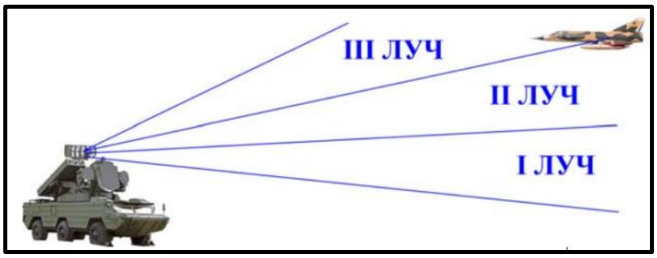
(The Krug was developed before the Osa but because of the structure of current document the Osa is explained first because it was on lower level in air defense organization. Osa was on divisional level SAM system while Krug was on army or even on front level.)

The 2K11 had one target and one fire channel per battery while a single 9K33 Osa vehicle is able to guide two missiles on a single target (one target and two missile channels) thanks to the double amount of antennas for each functions. The 9K33 Osa system has the following antennas see on the image below:



Main parts of the Osa-AKM variant.

1. СОЦ, (SOC) – Target Acquisition Radar (4 cm wavelength)
2. ССЦ, (SSC) – Narrow beam Monopulse Target/Missile Tracking Radar
3. ТОВ, (TOV) – Target Tracking Camera
4. Medium beam Monopulse Missile Tracking Radar for channels–I/II
5. Conical Scanning Wide beam Missile Tracking Radar for channels–I/II
6. Wide beam Missile Interrogator Radar for channels–I/II



With the SOC target acquisition radar a single Osa vehicle is able to search targets autonomously up to 45 km distance. (Against smaller target the detection distance is less.) The radar is able to measure (estimate) the altitude of the target thanks to shape of the beams of the radar. It can be determined the presence of the target in each beams/lobes but it does not provide exact altitude information. Similarly to Dvina/Volkhov and Neva systems (SA-2/3 families) this is enough precise to find and lock on target with quick elevation scanning in a certain azimuth direction.

The 1S11 radar of the 2K12 Kub system is also able to perform such altitude estimation but it has only two lobes.

The Osa similar to S-75/125 and 2K11 uses radio command guidance but it's working principle is different from any of predecessor system. The Osa got the later developed monopulse antenna technology for target tracking. Comparing to S-75M Volkhov uses both narrow and wide beam antennas either which has impact on the usable jamming methods as well as on SEAD activity with anti-radiations missiles. Osa had a very good almost ARM resistant capability against AGM-45 Shrike and AGM-78 only the arrival of the AGM-88 HARM changes this situation.

In normal cases as long as possible the target is tracked optically with the TOV target tracking camera. Finding the target optimally is supported by higher level IADS elements of the army air defense. Using the SOC radar is not necessary in this case. By using the TOV the Osa can operate without any radar emission until the launch of the first missile. The working principle of the guidance and radar system is the following:

- After the upwards launch of the missile (to avoid blinding the Karat camera with missile smoke), the wide beam antenna (white boxy '6' on the image above) starts emitting missile guidance signals. The mechanically rotating receiver (round green '5' labelled antenna) receives signals from the missile, and aims the whole gyro-stabilized platform (4-5-6 antenna group) towards the missile within 0.8 seconds after launch.

- After missile capture (0.8 seconds of the launch), the medium beam mono-pulse antenna ('4' labelled) is tracking the missile and guiding it to the beam of the narrow beam target tracker antenna ('2' labelled).

- When the missile signal is captured by the target tracking mono-pulse narrow beam antenna ('2' labelled), its guidance is continuing using it, and antenna 4-5-6 is resets itself.

In short all of smaller additional antennas comparing to 2K11 Krug are because to guide the missile eventually the single main lobe of the system. From that point the operation principle is similar to the Dvina and Volkhov systems during the whole guidance using three point guidance.

The Osa is able to perform only three point guidance[45] which is the worst solution against maneuvering targets. This design aspect is the result and direct consequence the experiences of Vietnam. In late 1967 only 4% of the Dvina guidance was possible with automatized tracking. In rest of cases because of electronic jamming targets had to be manually tracked which forced Dvina batteries to three point guidance.

To overcome the limits of guidance the missile was designed with 25G maximal turning capability as long as the engine is running. The maneuvering capability was designed accordingly to demand of the very specific guidance. In the early-mid '70s such turning capability was considered way above every other similar size missile. Even against the upcoming 4th generation fighters was suitable such performance. Against older fighters and attack planes such as F-4 Phantom II, A-4 Skyhawk or A-6 Intruder with subsonic speed and with much less maneuverability performance the Osa meant even higher threat.

The 9M33M2 (as well as M3) missile has dual thrust rocket engine (similar to US AIM-7F and AIM-7M) which ensures very good kinematic range considering the size and weight of missile. According the field manual the maximal engagement range of the Osa-AKM is 10.3 km up to 5 km altitude. Greek operators during field live fire training experienced this is quite a pessimistic value. Beyond this nominal engagement range the missile has enough kinetic energy to perform hard turns.

[45] https://www.youtube.com/watch?v=DnsIy4Pselo

Depending on atmospheric temperature the burn time of the rocket engine is 13-19 seconds (in 20 ^{O}C is about 16 seconds), burnout speed is about 640 m/s. Considering these values the missile can fly about 8-9 km until engine burnout therefore deceleration at 10.3 km has only slight impact on missile maneuverability.

The launch weight of 9M33M2 is 126 kg, warhead weight is 14,3 kg readiness time is 15 seconds because of gyroscope spooling up process.

Engagement limitations of with the 9M33M2 missile are the followings:

- Target speed 300 m/s (Mach 1,0) 25-5000 m altitude, 10.3 km range
- Target speed 500 m/s (Mach 1.6) 100-5000 m altitude, 10.3 km range

Engagement limitations of with the 9M33M3 missile are the followings:

- Target speed 100 m/s (360km/h) 10-25 m altitude, 6.5 km range
- Target speed 300 m/s (Mach 1.0) 25-5000 m altitude, 10.3km range
- Target speed 500 m/s (Mach 1.6) 100-5000 m altitude, 10.3 km range

With the more advanced 9M33M3 missile it is possible engage hovering targets down to 0 m altitude. The range of the 9M33M3 surpasses the range of the BGM-71 TOW ATGM which in the era of Osa was the longest range anti-tank guided missile on helicopters. The Osa AKM means still a considerable threat even for the AH-64A which has 8 km maximal engagement range with the AGM-114 Hellfire missile.

The first (initial) variant of the 9K33 was able to carry only 4x missiles (see on the left) which were stored on rails. This was the usual method for every contemporary SAM systems regardless is PVO or army air defense. For the later upgraded AK and AKM variants the carried missile capacity was increased to 6x. Besides the quantity boost it was introduced a new kind of storage for the missiles. They were stored in containers/canisters instead on placing them on rails.

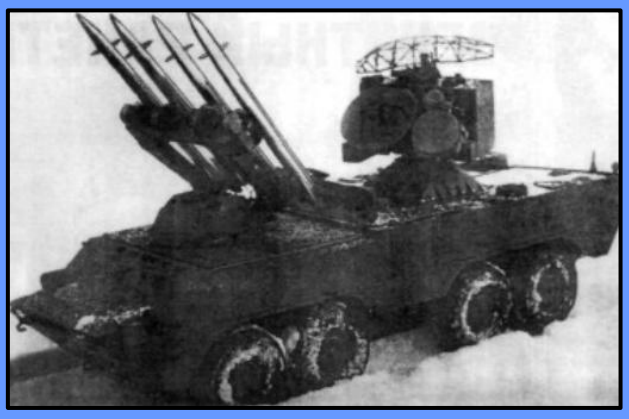
Similar to Strela-1/10 systems the Osa is amphibious but launching missiles is not possible during water crossing. For missile launch the vehicle has to stop and has to be on land. After stopping the vehicle the ready to launch state is achievable within 30 seconds. The turret can be turned ±330 degrees. A full rotation cannot be performed but it is possible to launch missile to any direction. This lack of rotation capability has to be considered during the engagement against close flying targets which flies nearby the system.

The Tetraedr company in Belarus have conducted an upgrade program on the Osa. The Tetraedr Osa-1T program involves a substantial rebuild of the legacy 9K33 weapon system. Using digital hardware replacing much of the legacy Land Roll radar system and supporting computer system for the automatic CLOS (command line of sight) missile guidance system. The upgrade includes new operator consoles & displays as well as a new electro-optical tracking subsystem.[46]

[46] http://www.ausairpower.net/APA-T38-Stilet.html

The birth of the Osa system was not an easy process. Because of the long and delayed development and production the Osa was the "black sheep" among the Soviet SAMs. When became available for NSWP countries and other 3rd World Soviet friendly countries many of them had to acquire the expensive 2K12 Kub (SA-6 Gainful) regiments for their best mechanized infantry divisions. This meant a serious burden for the economy of the Eastern Bloc countries.

The development of the predecessor system started in 1959 it was called Ellipse (see below). Among the design requirements was the 8 km maximal engagement range up to Mach 1 target speed between 50-5000 meter altitude. The system was designed to both for army air defense with launch during march capability and for naval air defense on ships.



The work started in NII-20 design bureau under the leadership of MM Kosichkin who had extensive experience in the development of small-sized mobile artillery radar systems. In 1967 the Ellipse was rejected because it was unable to launch full 360 degree in azimuth, unable to effectively engage targets below 100 m, unable to engage suddenly appearing target. The buoyancy of the vehicle was insufficient during of the trials one of the vehicle simply sunk.

Following the unsuccessful trial MM Kosichkin (above left) was replaced by V.P. Efremov (above right) he was appointed to lead NII-20 bureau. He proposed to delete the requirement of launching on the move capability however he suggested to keep the ability of detecting targets during march and offered a second missile channel. After a heated discussion of his proposals and despite several protests during the meeting, Chief Marshal of Artillery PN Kuleshov agreed on changes of the design basis. The original platform vehicle (Object 1040) was replaced with the BAZ-5937 chassis to increase the buoyancy. To reduce the weight and increase the azimuth coverage the separated launcher and radar turrets were rearranged into a single unit.

Following the successful state trials in October 4th 1971 the 9K33 Osa (SA-8A Gecko) was adopted with the capability of killing a single target with two 9M33M missiles.

Production: In '70-1, '71-3, '72-15. In '73 the 1st regiment was formed with 12 vehicles (a full regiment would consist 20 vehicles.) with the following engagement capability

- Target speed 300 m/s (Mach 1) 50-5000 m altitude, 9 km range
- Target speed 420 m/s (Mach 1.4) 200-5000 m altitude, 7 km range

Right after the fielding the modernization of the complex begun with the following requirements:

- Improving side visibility of the drivers. Training for the Red Square parade event showed that drivers could hardly keep the vehicles aligned for the parade.
- Capability of killing targets with 500 m/s (Mach1.6) speed
- Capability of killing receding targets up to 300 m/s (Mach1).
- Improving the missile overload capability to 25G.

One of the lessons learned from the ongoing War of Attrition (between Egypt and Israel) was that Soviet SAM systems strongly needed to increase the number of ready-to-launch missiles. DF Ustinov (Minister of Defense of the Soviet Union) ordered to redesign the 9K33 Osa to be able to carry double amount (8x) missiles. The lead designer objected because the payload limitations of the BAZ vehicle. The reply of the DF Ustinov was short:

"This is your concern, report on the execution!"

After investigation of the order Efremov called back the Minister.

"We have worked on your order about the possibility of installing eight missiles on the vehicle. Eight did not work but we could place six rockets in canisters."

DF Ustinov thought for a moment and replied:
"A black sheep is dreaming about white wool"

Following the decision in 1973 the Osa-A and Osa-AK upgrade programs were merged to create the new 9K33M2 Osa AK variant. Following the successful state trials in the second half of 1974 it AKM was fielded in February 1975. Export of the AKM variant started in 1980.

It was a funny side effect the redesigning process of the Ellipse system. Every army air defense systems in the Soviet Union were named after geometric shapes such as SA-6/K12 Kub where Kub means "cube". SA-7/9K32 Strela-2 where Strela means "Arrow". SA-4/2K11 Krug means "Circle."

Because the designers of the PVO SAM systems redesigned and finished the new army air defense SAM system it was renamed to Osa using the similar naming method as PVO SAM. It was a "gentle" reminder about who helped and replaced the original development team.

In my opinion the until arrival of Buk-M1 (even Buk is a much more robust system on higher organization level) considering the parameters of the system Osa-AKM was the most dangerous army air defense system in the world.

It was capable to carry lots of missiles none of the western SHORAD system had 6x missiles in ready to launch state. The minimal and maximal altitude of the engagement zone covered all the tactical targets in that era.

The missile was enough versatile to defat or just mean very serious threat even for 4th generation fighters. The range and engagement altitude made possible to engage any aircraft with any weapons before it could launch first. Even the best air to ground missile of '80s the AGM-65D-2 had smaller utilized engagement range then the 9K33M2 Osa-AKM.

In theory F-111F could bomb with laser guided bombs and Pave Tack above the engagement zone of the Osa. Only problem the F-111F had totally different targets in Europe. Using as a tanks destroyer during Operation Desert Strom was and exception and tanks were mostly stationary which is a totally different set up comparing to CAS requirements.

The anti-radiation missile (ARM) resistance of the Osa was also good considering the AGM-45 Shrike. It was almost impossible to attack the Osa. Because the narrow beam illumination only the AGM-45 carrier could launch the ARM if the Osa aimed on the ARM carrier. Only a very short time was available to react. Less than 25 seconds considering the maximal range of the Osa. The missile could hit the AGM-45 carrier and after the successful engagement the radar of the Osa could be turned off before the ARM get in range. Only the appearance of the AGM-88 HARM changed dramatically the situation because HARM can use the sidelobes of the radars for guidance. Regardless of the more advanced seeker of the HARM the short guidance and illumination time is a very serious limitation for any ARM.

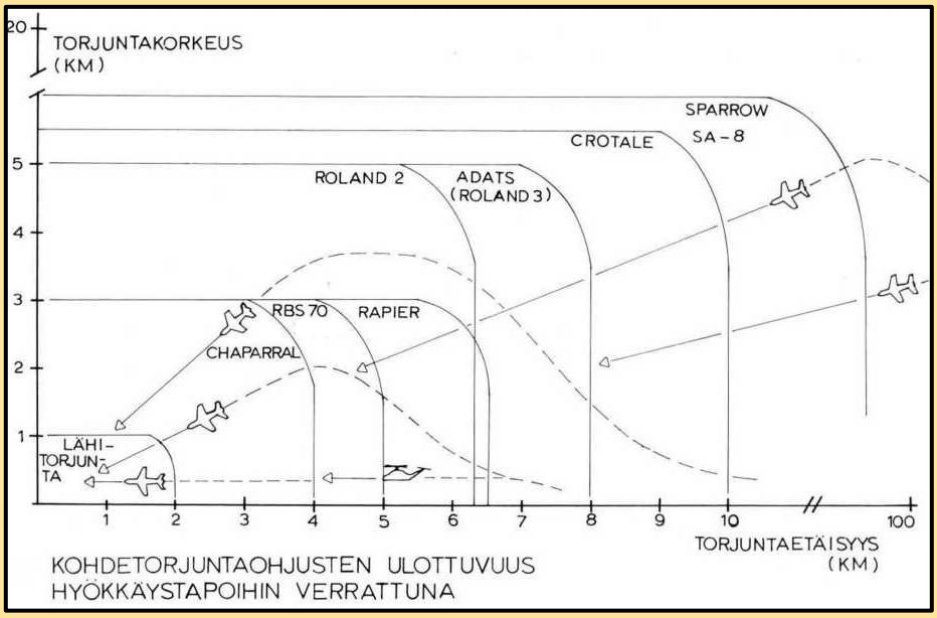
With adequate IADS support using the optical target tracking capability of Osa on paper it made the most deadliest threat what NATO air forces had to face it during the Cold War from the second part of the '70s. Only a handful or more advanced SAMs entered in service until the end of Cold War.

Considering the features and capabilities of the Osa it is very surprising how weak was the performance of the Osa during the Desert Storm. Until this day is no reliable and publicly available source what could cause this. The much older SAM systems were more successful than the Osa. For example one S-75M Volkhov battery successfully downed an F-15E Strike Eagle.

As usual finally below are some videos and images about the system
https://www.youtube.com/watch?v=QdeLa42kz_I
https://www.youtube.com/watch?v=14IhEMmItYk
http://www.ausairpower.net/APA-9K33-Osa.html

Not only the Soviet Union and NSWP countries but the NATO and other western world nations used and are using similar self-propelled short range SAM systems (SHORAD). Most of them had about "half level lower" engagement range zone. Most of western SHOARAD system during the Cold War had 6-8 km or even less range and maximal target altitude rarely was above 3 km.

Such system was the joint developed German-French Roland, the English Rapier, the French Crotale[47] and post-Cold War Crotale NG as well as the less known ADATS[48] and the failed American Mauler[49] which never entered into service. These systems typically used radio command guidance method. The difference was mostly in the exact used method of target and missile tracking comparing to 9K33 Osa family.



For example the Crotale R440 instead of radio tracking used infrared sensor to guide the missile into the main lobe[50] of the target and missile tracking radar while the 9K33 Osa used lots of smaller antennas. Very likely the Crotale can perform only three point guidance similarly to Osa. The engagement zone of the Crotale is different from the 9K33 Osa. Because the kinematics of the missile the real engagement zone is smaller.

At 5, 6, 10 and 13 km distance the missile is able to perform 27, 18, 8 and finally only 3G turn. Considering the three point guidance it means against maneuvering targets the real engagement range in only about 5-6 km. The missile of the Osa is able to perform about 20-25G turn even at 10.5 km range.

The Crotale does not have target acquisition radar on the launcher vehicle while the Osa has. This kind of radar is on another vehicle which means the system is less compact and unified. The 9K33 Osa is also very unique because of its amphibious capability.

47 http://www.ausairpower.net/APA-HQ-7-Crotale.html,
48 http://www.designation-systems.net/dusrm/m-146.html
49 https://www.secretprojects.co.uk/mauler.pdf
50 http://www.ausairpower.net/PLA-IADS/Crotale-IDR-1-1970-Figure-1S.jpg

Above left is the French-German Roland on the chassis on the Marder IFV on right is the launcher vehicle of first Crotale system

Western designers many times followed total different basis of design. The 9K33 Osa-AKM has 6x missiles ready to launch. In comparison most of NATO SHOARD in the same era had only 2x or 4x but with different conception.

For example the Roland Marder 2 radar SHORAD vehicle has two missiles ready to launch in canisters. The system has only a single target and missile channel and only with 6.3 km range up to 3 km altitude. It has no use to have more than two missiles for ready to launch because of the short engagement range. It is no time than launch and guide more than two missiles. Following the quick reload process which it takes less than 10 seconds the next pair of missiles are ready to launch against another target.

The total inventory of the Roland is 10x missiles. The fire rate of the 9K33 Osa-AKM is higher up to 6x missiles but after that a much more time consuming reload is needed. The Roland remains combat capable longer because it has more and smaller missiles but with less range and has only a single target channel. But the price of the two missile channels of the 9K33 Osa is very high. It took too long to develop and made very complicated the whole system.

Some of the western SHORAD systems are on the video links below.

https://www.youtube.com/watch?v=YYtop83C6yU

https://www.youtube.com/watch?v=USh97KrOMjY

It is interesting USA initiated many SHORAD and AAA developing programs. For example the Roland SAM program for a while was a joint German-American development. Also the USA designed the Mauler system with SARH guidance as well as the failed M247 Sergeant York[51] and the M48 Chaparral. Despite the efforts only the M48 Chaparral was entered in service as an interim solution. Eventually it was used more than 30 years and many times have been upgraded. Since the mid '90s USA does not have any SAM system between the Stinger missile based Avenger and the long range Patriot system. Both the HAWK and M48 Chaparral retired in '90s.

Despite the NASAMS/NASAMS2 uses the American AIM-120 AMRAAM (other missiles are also available such as ESSM Block 2 or AMRAAM-ER) they use only defend the White House and the Pentagon in such small quantity which can be considered only anti-terrorist role.

[51] *https://www.youtube.com/watch?v=ogDgLOJOKJs , https://www.youtube.com/watch?v=TanFPsRaeto*

9K331 Tor-M1, 9K332 Tor-M2 (SA-15 Gauntlet)

The Tor was developed for the successor army air defense system of both the 9K33 Osa and 2K12 Kub families even it has less considerably smaller engagement range than the 2K12 Kub-M3.[52]

The first Tor variant was manufactured in very small quantity with 9K330 designation. This initial variant was the foundation of the further developments but it was just a "rebalanced and upgraded Osa". It was the a technology demonstrator the next iteration for division level air defense following the very problematic predecessor. The 9K330 GRAU designation is similar a reminder about the evolution what was explained at the Ellipse ---> Osa renaming history. This time the 9K33 just got an extra '0' in designation showing its relation to the Osa.

In the previous chapter was mentioned Ustinov demanded 8x missiles for the upgraded Osa variants but only 6x was doable. Fulfilling this requirement was one important for the Tor system. Besides the increased carried missile quantity the most crucial upgrades were designed for the radar and guidance. Following the painful and long developing the 9K33 Osa it became obvious increasing missile and target channels in conventional way with more antennas is not an option. Another solution had to be found to increase the quantity of target channels and other capabilities of the Tor.

In the early-mid '70s was developed for homeland air defense the first version of the S-300 family with PESA technology fire control radar . This was the 30N6 (Flap Lid) fire control radar of the S-300PT. The development of the S-300 was successful therefore the similar base technology was adopted for the Tor. Of course the applied technical solutions of the S-300 had to be downscaled accordingly to fulfill the requirements of the army air defense. Everything had to be installed on a single vehicle similarly to the 9K33 Osa.

The 9K331 Tor-M1 is literally a miniaturized S-300PT with similar missiles to 9K33 Osa in kinematics and size but with a bit larger weight. The guidance is similar to the S-300PT. The Tor vehicle is self-contained the fire control and target acquisition radars are on the same vehicle as well as the missiles. Of course the engagement zone of the Tor-M1 is much smaller than the S-300PT and it has only 2x target and 4x missile channels. (The 300PT has 6x and 12x respectively.)

[52] *Range is not everything other capabilities are also important as well as the cost efficiency concerning of target channels and defended area.*

9K331 Tor-M1.

The 9K331 Tor-M1 has the following main elements:

1. СОЦ, (SOC), target acquisition radar with the IFF antenna (cm wavelength)
2. Wide beam missile guidance antenna
3. Narrow beam monopulse target and missile tracking radar, also is used for RCG signals
4. Optical target tracking system (TV camera)
5. Missile containers, on each sides with 4x missiles, in total 8x missiles for Tor-M2. For Tor-M2 smaller missile is available with 8x missiles/container.

We can see the quantity and types of the antennas comparing to Osa is strongly reduced. The advance in solid state electronics technology and the PESA radar made possible to achieve these changes. Following the missile launch with '2' labelled antenna is guided the missile into scan zone of the '3' labelled PESA antenna which tracks both the target and missiles and emits the RCG signals for the missiles.

Comparing to many antennas on the 9K33 Osa only a single small wide beam antenna is enough to guide even four missiles into the narrow beam ('3') antenna. The latter larger PESA antenna fulfills three different roles thanks to the PESA radar rapid and free azimuth and elevation scan capability. Within It can track both the missiles and targets. It is able to illuminate all of them dozens of times within just a second while also transmits RCG signals to the missiles. The 9K330 had only a single target channel but the first major variant the 9K331 Tor-M1 has 2x target and 4x missile channels. Tor-M1 became the first army air defense system with simultaneous engagement capability **with a single fire control radar**.

This was a great step forward comparing to the Osa's single target and two missile channels. Comparing to a single 2K12 Kub regiment (with five batteries) two Tor-M1 vehicles have the same target channel qty. if we consider such full regiment where one of the battery is under relocation. Of course the covered airspace is smaller but the target channel density is higher for Tor-M1. In the '80s the maximal 6 km engagement altitude was more than enough. None of airplanes in service and forecasted tactical aircraft could use effectively any strike weapons above 6 km not even laser guided bombs at that time. (Only a handful of airplanes could use laser guided bombs in the '80s.)

Similarly to Osa the Tor-M1 also has the autonomous target acquisition capability by the SOC radar. Besides the SOC is stil the data link with higher IADS elements is the preferred and better way to get target coordinates while the Tor-M1 itself can remain hidden until missile launch.

The 9M331 missile is launched vertically with gas catapult system similar to S-300.[53] Following the launch on the tip of the missiles the gas dynamic control system rotates the missile towards to the target then main rocket engine is ignited and accelerates the missile up to M2.4. The launch weight is 167 kg, warhead weight is 15 kg.

This combined launch method was necessary to achieve the very small engagement range with vertically stored missiles in canisters instead using rotated turret as happened with the Osa with its own design limitations. The gas dynamic system prevents to waste kinetic energy for turning the missile from vertical direction towards to target when the missile very quickly accelerates from zero speed until burnout the main rocket engine. For rotating the missile around its center of gravity requires very small but precisely controlled thrust. The gas dynamic system solution not only increases the maximal engagement range but also has good impact on the minimal engagement range.

Launching of the 9M331 missile. It is visible the still operational gas dynamic system on the tip of the missile while the main engine of the rocket has been ignited.

Comparing to Osa the GM-569 platform vehicle is totally different. The amphibious capability was not requested because both the ZSU-23-4 Shilka and the predecessor 2K22M Tunguska do not have this feature. Regardless the Tor-M1 is division level it is assigned to battalions. (See in the structure and organizations chapter.)

The Tor-M1 is much more automatized then Osa. This is required for the “anti-ARM” and for the navy the “anti-ASM” capability demand. The Tor-M2 has even fully automatized mode.[54]

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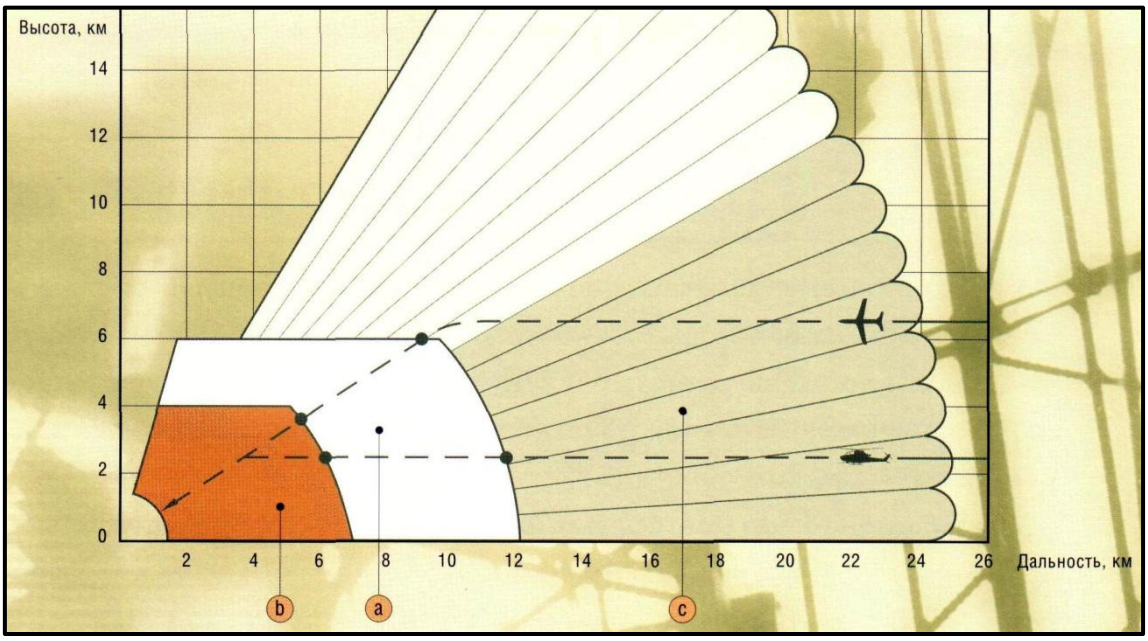
53 *This is what called „cold launch”. For S-300MPU on a „plate” is placed the missile and there are two pistons in the canister. Using powder charges as gas generators the expanding gas provides the power for the pistons. The pistons push the plate and the missile on the plate. This ejects (launches) the missile 20-25 meters above the launcher vehicle. Very likely the Tor uses the same technical solution. (Hpasp)*

54 https://www.youtube.com/watch?v=y8f6l-UN_9M

A very useful and new feature that Tor-M1 is able to shoot down incoming anti-radiation missiles. In the era of AGM-88 this was a big capability boost comparing to Osa and Kub.



Engagement and search zone of the Tor-M1 system. The maximal engagement altitude is 6 km up to 12 km distance against airplanes.

The maneuvering capability of the missile is slightly increased to 30G max turning capability. The burnout speed is between 700-800 m/s (M2.1-2.4) depending on the trajectory of the missile. The minimal engagement distance is 1.2 km Minimal target altitude is 10 meter. The maximal target offset distance (parameter) is 6 km. Maximal target speed is 700 m/s but in this case the parameter distance is likely smaller.

Above left is on self propelled wheeled vehicle on the right tracked variant accordingly to demands of the polar regions.

Besides the „classical" self-propelled tracked GM-569 chassis other options are available as platform for the missile system since the early 2010s. Accordingly the special Russian requirements in polar and certain regions were these developed and of course for potential foreign customers.

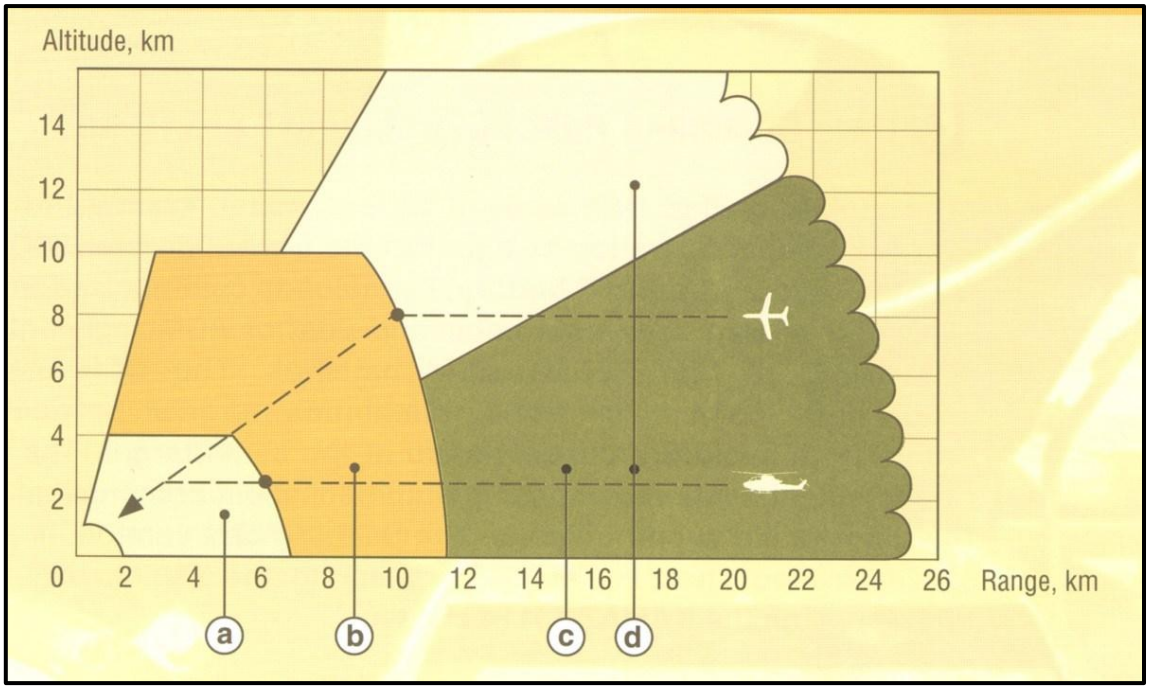
In 2007 on the MAKS exhibition was presented first the latest iteration of the SA-15 family. The 9K332 Tor-M2 variant which entered service from 2012 in Russia. The M2 has almost the same appearance as the M1 variant . The main differences are the new antenna of the SOC and the additional wide beam missile guidance antenna. Thanks to the new wide beam antenna and other upgrades the Tor-M2 has 4x target and 8xmissile channels. Besides the increased target quantity channels the Tor-M2 has a new

smaller missile the 9M338 likely with smaller engagement range and warhead against missiles and cruise missile and drones.

Above left is the Egyptian Tor-M2 on the right is a Russian Tor-M2. On both pictures are visible the new additional wide beam antenna.

Because of the smaller size of the 9M338 in a single canister 8x missiles can be loaded. The total inventory can be increased to 16 missile if the new missiles are used exclusively . It is possible to use mixed missile inventory in this case the maximal missile capacity is 12x missiles 4x9M331 and 8x9M338. The engagement range with larger missile reaches 10 km maximal altitude and 15 km range.[55]

The idea behind the more but smaller quantity of missile very likely the increased quantity of smaller targets on battlefield such as UAVs and UCAVs and smaller but more abundant strike weapons per attack aircraft such as GBU-39/53 (SDB I/II) or Brimstone missiles.



Engagement and search zone of the Tor-M2 system. The maximal engagement altitude is 10 km up to 15 km distance against airplanes.[56] Zone 'a' shows the engagement range against ARMs and slower bombs.

[55] https://goo.gl/mZVQje

[56] https://goo.gl/sfZf2t

The Tor-M2 is able to launch missile during slow movement on paved road. This was originally was demanded from the Ellipse system. **50 years ago before** Tor-M2. Tor-M2 is the first radar SHORAD system in t he world which is able to launch and guide missiles during movement.

The Tor-M1 became available after the Cold War and very soon was offered for export similar to S-300PMU1. So far only a few were sold outside Russia which is hard to understand because of the capability of the system. Even the Tor-M1 provides unique capabilities and range in radar SHORAD category and the Tor-M2 is more advanced. About half a dozen countries bought Tor-M1 or M2 if we do not count the successor states of the Soviet Union. Regardless of the exports only a very few countries booth more than a dozen.

As usual finally below are some videos and images about the system:

http://www.ausairpower.net/APA-9K331-Tor.html#mozTocId239351
https://www.youtube.com/watch?v=9MZtnqJLf4c
https://www.youtube.com/watch?v=N7vvvgodLU8
https://www.youtube.com/watch?v=8YI72CSiexQ
http://www.ausairpower.net/APA-9K331-Tor.html

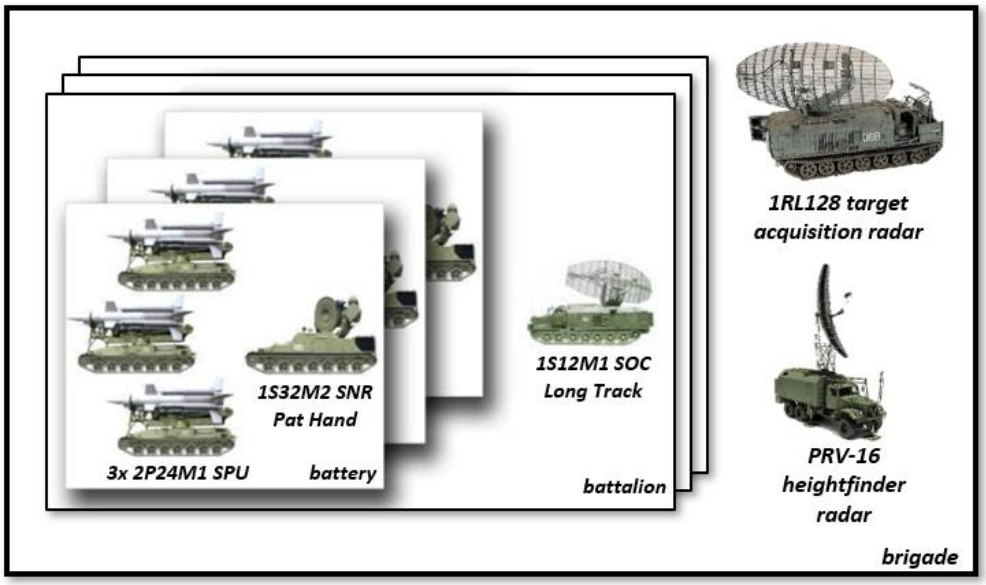
2K11 Krug (SA-4 Ganef)

The 2K11 Krug (SA-4 Ganef) was the first fully mobile radar guided SAM system in the world. It was developed by the NII-20 bureau during the leadership of V.P. Efremov. The Krug was revolutionary in many areas. Many of its technical solutions and capabilities were also unique during the whole Cold War.

Because of some its features regardless in some aspects was outdated even in late '70s the Krug system never was exported outside the Warsaw Pact. It had extraordinary features against anti-radiation missiles. The Krug system used radio command guidance similar to contemporary S-75M and S-125M systems. but they way as it used made the Krug totally different.

Krug was the first Soviet SAM system which used the monopulse target tracking method and had an built in analogue computer. It was fully NBC (Nuclear Biological Chemical)[57] protected by filtered over-pressurization system. The Krug was able to achieve the launch ready state only 5-15 minutes following the stop and deployment order. In the era where the S-75M Volkhov or S-125M deployment time was measured in hours this made extraordinary the system. In fact this was the requirement army air defense.

The Soviet Union fielded the first version in 1964. The Krug was constantly improved during its lifetime resulting in the Krug-A, Krug -M and finally the Krug -M1 variants.



Above is a Krug battalion with three batteries A brigade has three of such battalions a regiment has only two. (Hungary instead of full unit used only 2/3 of a brigade and it was called regiment.)

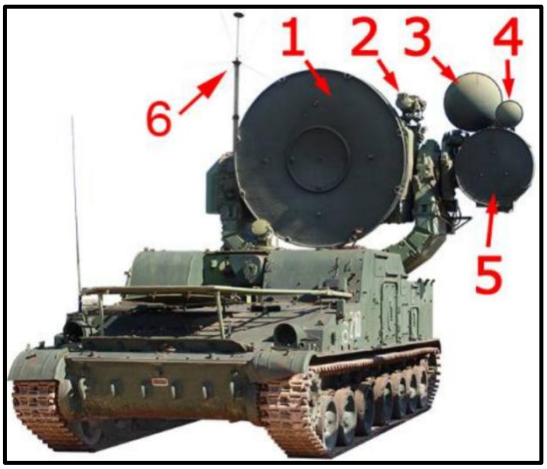
The smallest element of the Krug brigade (or regiment) is the battery. One battalion has 3x batteries. One Krug brigade 3x three battalions, one regiment has 2x. The main equipment of the Krug-M1 systems are the followings:

[57] *As every army air defense system which was developed later.*

- 1S32M2 SNR (Pat Hand) self-propelled mobile fire control radar, one for each battery
- 2P24M1 SPU self-propelled mobile missile launchers 3x for each battery, 2x3M8(M3) missiles on each self-propelled tracked launcher
- 1S12M1 SOC (Long Track) self-propelled long range target acquisition radar, one for each battalion
- One P-40 complex for each regiment or brigade,[58] 1RL128 long range target acquisition radar and one PRV-16 heightfinder radar

The 1S32M2 SNR fire control radar (guidance station) has the following antennas:

1. AVS-I monopulse target tracking antenna. (RPC)
2. TOV camera (optical target tracking)
3. SPK missile command transmitter antenna (called "RPK," Russian acronym for Radio Command Transmitter).
4. AVS-II wide beam missile tracking antenna (receive only).
5. AVS-II narrow beam missile tracking antenna (receive only).
6. retractable antenna of the 1S62 and 1S63 wireless digital data link system.



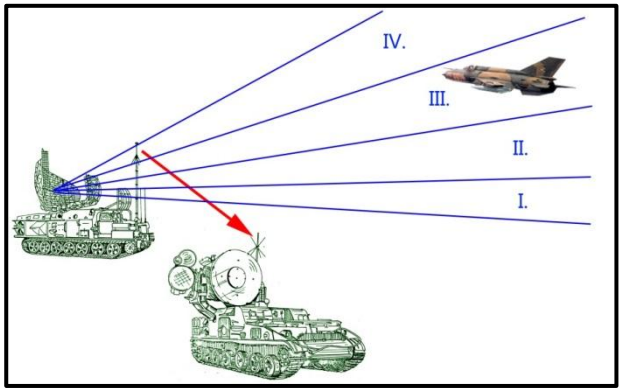
We can see the 9K33 Osa inherited many designs and technical aspects of the 2K11 Krug. Comparing to the SA-75 Divna and S-75M Volkhov (SA-2 family) one of the major improvement was guidance and leading method. The Krug was the first Soviet SAM system with independent target (AVS-I) and missile (AVS-II) tracking radars. Because of this new antenna design it could guide the missile against the target with larger lead angle than the earlier eastern systems which provided much optimal trajectory (less G demand in turns) and made possible to **intercept even ballistic missiles** up to 800 m/s speed.

The target is tracked with the '1' labelled antenna, RCG signals are emitted with the '3' labelled antenna and the transponder signals from the missile are received with '4' and '5' antennas. Following the missile launch the wide beam antenna is used at longer distances the narrow beam antenna takes over the role. (Osa inherited this design.)

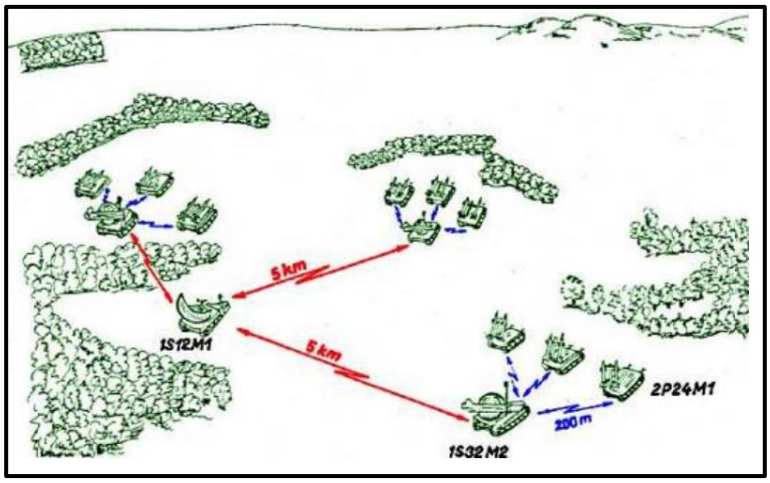
Against smaller size targets (MiG-21, F-104, F-5) the SNR detection range is about 70-80 km the maximal displayed range on the scope is 110 km. Target tracking above 110 km is not possible. The turret of the SNR can be turned ±320 degrees but full rotational is not possible (similarly to Osa).

[58] *The 1S12M1 should not be mistaken with the P-40 complex with the PRV-16 + 1RL128. Regardless the similar appearance of the 1S12 Long Track and 1RL128 are very similar they are on totally different organization levels.*

For target acquisition each battalion has the 1S12M1 SOC radar. In case of need very limited and slow search is also possible with the 1S32M2 SNR guidance station by using its monopulse target tracking antenna (‘1’). The UHF band SOC nominal detection range against fighters is about 200 km. The SOC is connected to the SNR with 1S62 digital wireless datalink antenna or P-274 cable telephone connection.



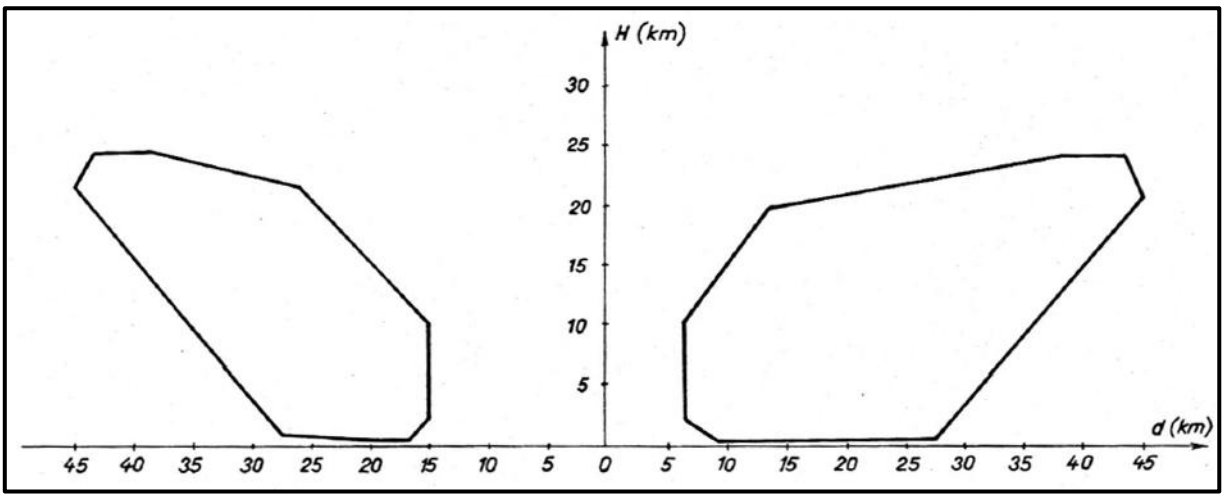
By consecutively scanning four elevation sectors (I., II., III., IV.), the 1S12M1 SOC radar is capable of acquiring not only the range direction of the target and but also the approximate elevation (altitude). These data can then be forwarded across the 1S62 wireless digital data link to the 1S32M2 SNR. (The SOC radar of the 9K33 Osa inherited this altitude estimation capability too from the Krug.) By using the digital wireless datalink the deployment distance between the SOC and SNR can be 5 km.



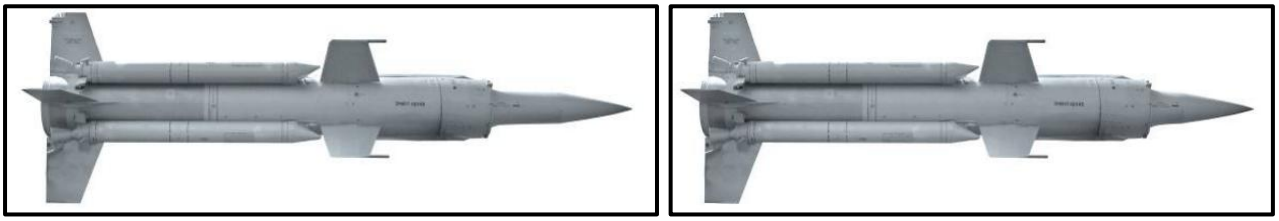
The SNR processes automatically the data from the SOC and following a short scan in elevation and azimuth automatically tracks the designated target. The further activity of the SNR is handled by the analogue computer (SRP). It calculates the numerical parameters of the engagement zone as well as the azimuth and elevation settings of the antennas and finally the direction of the missile rails of the launchers (SPUs). The SPUs receive the data via internal datalink. Following the targeting processes antennas and the launcher(s) are set towards to the target.

When the target enters into the launch zone (not the engagement zone) the missile can be launched. The commander of the battery selects the missile and gives the order for the launch. Following the launch the missile enters into the gate zone where the wide beam antenna (‘5) intercepts the missile and guides into the narrow beam (‘4) antenna’s lobe. Using the received data from the missiles trajectory is corrected by the SNR. The warhead is armed only in terminal phase as well as the radio proximity fuse.

The 2K11 Krug had only a single target and single missile channel which meant in this area was a step backward comparing to S-75M Volkhov or even the S-125M Neva which they had three and two missile channels. Maximal target speed was 800 m/s, maximal engagement altitude was 24.5 km up to 50 km distance.



Engagement envelope of the Krug-M1 in case of 0 km parameter (offset) distance against incoming (above right) and receding (above left.)



Above left is the 3M8 missile above right is the 3M8M3 variant. The differences are minor but important at the nose section.

The missile of the Krug was partially similar to homeland air defense (PVO) SAMs. The missile was designed with two stages with solid propelled boosters, the main engine still was liquid propelled as the contemporary S-75M. But for a mobile army air defense system it was unacceptable to use the very toxic liquid fuel of the Dvina/Volkhov because frequent relocations and possible incidents during the process. Before of safety reasons the missile used kerosene fuel.

The booster stages was separated about after 4 seconds the main engine worked about 65-72 seconds. The burnout speed was about 800 m/s depending on the altitude and the trajectory. The main engine was a ramjet engine which had serious impact on the maneuverability of the missile. Its design prevented the high angle of attack turns which limited the available maximal G in turns. For the 3M8 missile variant 4G was the maximal even the redesigned and upgraded 3M8M3 missile was capable to perform only 6G.

The launch weight of different missile variants were almost the same about 2450 kg. It made similar in size and weight to missiles of the S-75 Volkhov. It is worth to compare the 9M8M3 to missile of the Kub-M3's 3M9M3 missiles. The latter has about **half size** engagement zone but the weight of the Kub's missiles **is only the quarter** of the Krug's. The radio command guidance demanded huge 150 kg warhead because the accuracy decreases as target distance increases.

Because of the solid propelled non-jettisoned first stage, the SARH guidance and less range the 3M9M3 is far more smaller and lighter proportionally as is excepted by first look.[59]

[59] *Hungary bought later the 2K11 Krug then the 2K12. Because of liquid fuel 2nd stage and much complicated systems and limited support from the USSR the Krug was mostly disliked by its crew regardless of much larger engagement range. In Czechoslovakia interestingly the case was opposite they mostly liked the Krug.*

One of the unique feature of the 2K12 Krug it's anti-ballistic missile (ABM) capability against short range tactical ballistic missiles such as MGM 52 Lance of the French Pluton. Their terminal velocity was within the limits of the Krug and leading was possible because of the independent target and missile tracking radars.[60]

Another unique capability which could be a well utilized feature the way as the SNR and the SOC worked. The Krug can be called and "analogue LPI"[61] SAM system. [62]

In case of Programmed Target Tracking ("ПНС") mode the monopulse target tracking antenna. (AVS-I) does emit. The antenna turret is controlled by the built-in onboard analogue compute (SRP) comparing target location data from the 1S12M1 SOC (Long Track). The forecasted (extrapolated) trajectory by the computer is compared to what the SOC measures. If the difference is larger than 7 km the SNR for a moments illuminates the target to measure accurate location of the target and be able to correct the trajectory of the missile. If the target does not (or cannot) detect the radiation from the SNR and does not make any defensive maneuvers (turns) the continuous illumination by the SNR using the AVS-I antenna is not required. This is why is can be called "LPI" the SOC uses different wavelength then the SNR therefore the target is not aware of the missile launch.

During the Periodical Illumination Target Tracking Mode the SNR is silent for a period which is calculated by the SRP (onboard analogue computer). The SNR emits (to update the target's path) only the shortest required time by the monopulse method **about only 1 second**. While the SNR is silent it cannot be detected by the enemy's RWR (Radar Warning Receivers). Another benefit cannot be launched ARM for example AGM-88 HARM. Regardless the AGM-88 is so advanced and can use the sidelobe of the radars if the radar is silent is does not produces any source for target tracking...

During the Operation Allied Force in 1999 became obvious even the AGM-88 has memory and tried to "memorize" the location of the target in case the target radar went silent the probability of hit even the best ARM in the era was surprisingly low. AGM-88 HARMs mostly missed their targets in case the radars were turned off enough soon. (Suppression mostly was achieved but destruction was not.) If the SNR is on and emits only for very short time (about 1 sec) and in random moments the task for ARMs is really, really hard comparing to any Cold War era SAM system.

This was very likely one of the key factor why never was exported outside the Warsaw Pact the 2K11 Krug. The SA-4 retired in every ex. WPACT member countries until the early 2000s. Only a meaningless quantity remained in service in successor states of the Soviet Union. It was totally outdated system is the post Cold War era.

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60 *They only Hungarian unit (in Keszthely) never practiced against imitated BM targets.*

61 *low probability intercept http://www.radartutorial.eu/02.basics/LPI%20radar.en.html*

62 *See in the manual of 2K11M1 Krug-M1 Simulator by Hpasp.*

Considering the features of Krug we can say it is a very contradictory SAM system. During the ’60, the ‘70s and against many airplanes in the ‘80s the detection of the missile launch could be very problematic with RWR. Regardless the Krug was the child of early ‘60s the very short SNR usage made it a very unique even compared to the modern systems.

If a launched missile cannot be detected visually by the pilot the Krug could mean a serious threat for any airplane regardless the maneuvering capability of the missile was ridiculously weak comparing to any SAM systems. If the pilot cannot see or detect any way the incoming missile the task is simple for the Krug. A non-maneuvering airplane has to be hit.

The problem if a pilot could spot the missile it was very easy to dodge it. The maximal 6G turning capability of the 9M8M3 missile was similar to first version of the SA-75 Dvina. The missiles of later developed system reached 10G (S-75M Volkhov, S-200V Vega), 12G (S-125M Neva below 10 km altitude) and 15G (2K12 Kub). against tactical fighters at the most typical combat altitude range. Of course sometimes is hard to detect the missiles regardless of their strong smoke trails.

Assuming the worst from the point of view of the Krug. If the short emission of the SNR can be detected by RWR the task is easier for because the main direction of the threat is known. During Vietnam similar or slightly more agile missile dodged by American pilots many thousands times. The missiles of the Dvina had similar max. G limit as the 9M8M3 missile. With the first 9M8 missile considering its 4G maximal turning capability for any tactical airplane would be child’s play to dodge the incoming missile. The SA-2 family was able to guide three missiles on a single target the SA-3 could two to make harder the evasion by maneuvers. The single fire channel capable Krug was not able to make harder the task regardless the additional missiles on the launchers.

Regardless how shiny it looks on paper LPI capability its effectiveness is partially questionable. **It demands the continuous operation of the SOC**. Because the SOC and SNR are quite close to each other (max. 5 km) if the SOC is located by RWR a pilot can be sure about direction of the main threat. From 50-60 km distance in worst case is about 10 degree wide the zone from the missiles can be expected.

For being aware of launch has to be know the operation of the SOC. Checking visually the airspace towards to the SOC considerably increases the chance to spot visually the incoming missile. Of course this aid is much less comparing to a functional and reliable RWR detection. The SOC uses dm wavelength which is not the best for RWR of tactical airplanes. The RWRs are optimized against cm wavelength fire control radars. Detection of the SOC is easier for electronic warfare assets.

Considering all the factors above we can say tactical airplanes in some cases easily could dodge the missiles. It is also not an over statement it was close to impossible to destroy the SNR with AGM-45 Shrike. Thanks to its very short and intermittent emissions and the narrow beam antennas comparing to wide beam Dvina in Vietnam.

The problem is the continuous SOC operation. The PVO SAMs used the P-12/18 target acquisition radars with **meter wavelength** which made them immune to any ARMs. Even during the Allied Force in 1999 Zoltan Dani sometimes used the P-18 for 12-24 hours without relocation while he restricted his own units to 21 seconds operation with SNR-125 guidance station with cm wavelenght.

The SOC used dm wavelength which could be attacked even with AGM-45[63] but only from close. Also could be done with AGM-88 from literally any direction. Of course going close to a Krug battery is not so easy because of the layered Soviet army air defense. The anti-SEAD capability of the Krug was seriously reduced with arrival of the AGM-88 in the mid '80s.

It has to be noted the AGM-88 at the end of Cold War was almost exclusively used by the USA. Other NATO members acquired considerable less quantity sometimes only after end of the Cold War. Even the USA still used the AGM-45 during the Operation Desert Strom in 1991.

But not only the AGM-88 HARM was the issue. Against 4th generation fighters the maneuvering capability of the 9M8M3 missile became totally inadequate.

As usual finally are some video and about the system:

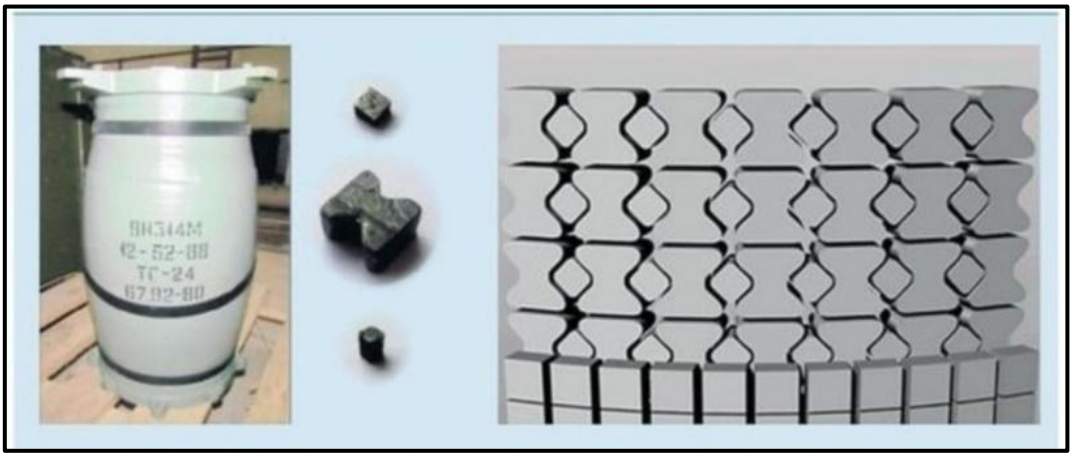
https://www.youtube.com/watch?v=My0Xr-ITrW8
https://www.youtube.com/watch?v=5rseSkU8yD8

[63] *http://www.designation-systems.net/dusrm/m-45.html AGM-45 had seeker in cm wavelength.*

9K37M1 Buk-M1, 9K37M1-2 Buk-M1-2 (SA-11 Gadfly)
9K317 Buk-M2, 9K317M Buk-M3 (SA-17 Grizzly)

The Buk-M1 was the first joint Russian naval and army air defense SAM system which was designed ground up[64] for both branches of the armed forces. Regardless the strong political pressure (from DF Ustinov) the army disliked and resisted to accept it. The navy wanted a new SAM system against massive anti-ship missiles (ASM) salvos such as AGM-84 Harpoon or the Exocet. These weapons are able to perform se skimming approach. Besides the low level capability lots of target channels were requested.

The army wanted an effective long range missile against the A-10 Thunderbolt II (and other airplanes). The requirements of the army caused headaches for designers concerning on the warhead. Finally the butterfly shaped pre-formed shrapnel was proven to be enough effective for both roles. The anti-ship missiles (ASM) are soft comparing to A-10 but are much smaller while the A-10 is larger but a harder target. These were the cornerstones of the design.



We can see later the minimal engagement of the Buk-M1 is only 15 meter but AGM-84 Harpoon can fly below this level. But the effect of the proximity fuse has to be considered which maximal sensitivity is 20 meters. This makes possible to shoot down AGM-84 or other sea skimming ASM flying at 10-15 meters. The missile approaches from above the target therefore the surface of the water is not a problem.

Even in the era of S-75M Volkhov was a priority the reducing the sensitivity of the proximity fuse to achieve smaller minimal engagement altitude. Despite lots of efforts the minimal engagement altitude of the S-75M was only 100 m.

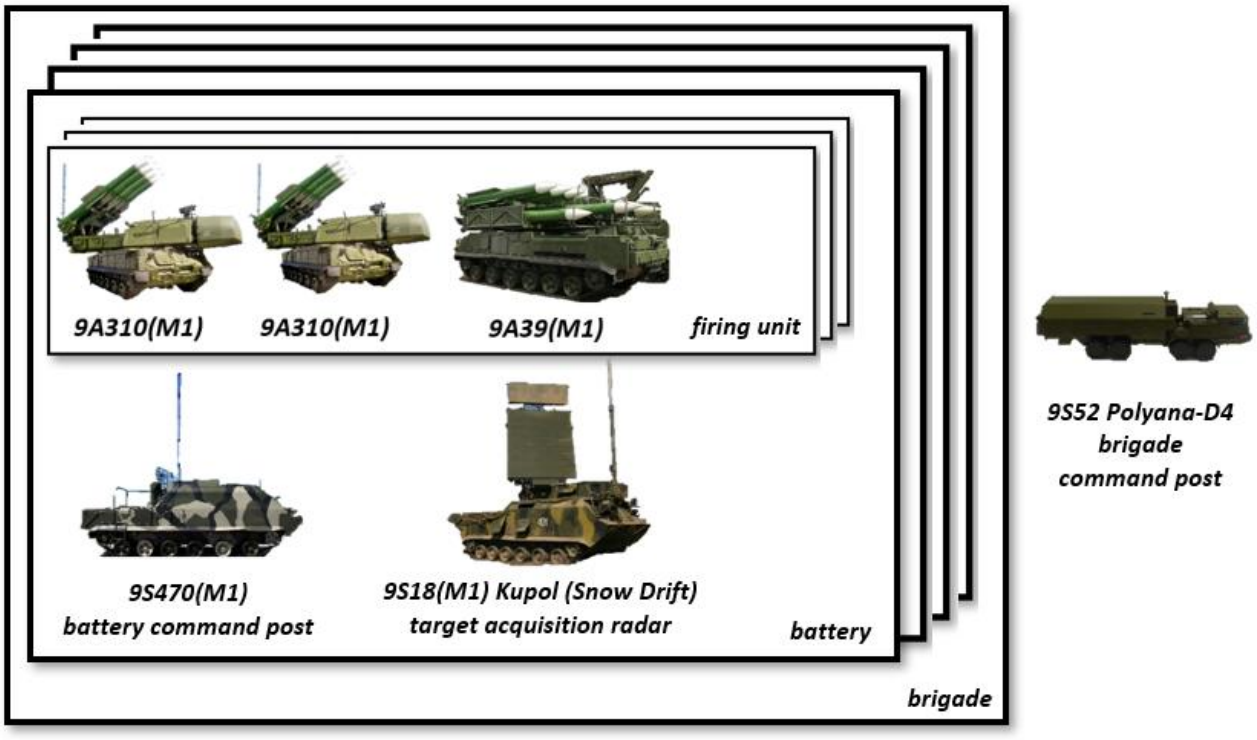
Before the development of the Buk the conception of it partially manifested as the proposed 2K12 Kub-M4 variant in 1978. The M4 variant kept the chassis of the Kub as well as the missile but the missile launcher (TEL, transporter erector launcher) was converted to a TELAR (transporter erector launcher and radar) using the 9S35 (Fire Dome) fire control antenna system. With this major design change the new TELAR could use the 3M9 type missiles of the 2K12 Kub (SA-6) as well as the new 9M38 missile of the new Buk system (upward compatibility). Both missiles types could be guide by the TELAR instead the SURN of 2K12. The available missiles per launcher remained three.

64 *Many other SAM systems used by both the army and the navy see in later chapter.*

Technology demonstrator of the Kub-M4 TELAR (transporter erector launcher and radar).

The 2K12 Kub-M4 never was mass produced neither the early 9K37-1 Buk-1 variant. In early stage of the development the 9A38 SOU (TELAR) was assigned to a 2K12 Kub battery. This addition increased the target channels two from one (1x1S91 SURN + 1x9A38 SOU) per battery and quantity of the missiles is increased four with larger engagement range. The new TELAR was designed to use the missiles of the older Kub system as well as the new missiles (backward compatibility).

The conception of Buk-1 was rejected and the 9K37M1 Buk-M1 conception was accepted finally in 1983. The first full Buk-M1 brigade entered in service in about end of 1986 or early 1987. The Buk-M1 was designed to a higher level air defense than Kub. The Buk-M1 replaced the 2K11 Krug.



A 9K37 Buk-M1 brigade has four batteries the main units of the batteries are on the diagram above. Each batteries has three firing units. In total the brigade has 12x batteries (while the Krug had only 9x).

The brigade has one brigade command post (CP) vehicle the 9S52 Polyana-D4. The brigade CP is on higher level above all the batteries. The brigade CP coordinates the work of on army group level besides being the CP of the Buk-M1 brigade.

Each battery has one Kupol 9S18(M1) target acquisition radar, one the 9S470(M1) battalion command post vehicle and three firing units.

Each battery has two 9A310(M1) SOU (TELAR) and one 9A39(M1) PZU (TEL). The TELAR has 1x target channel and 4x missiles, the TEL has 8x missiles. Besides being as a fully functional launcher the TEL also acts as the reloader or TELARs.

Above left is a 9A310M1 SOU (TELAR) on the right is an 9A39M1 PZU (TEL) launcher and missile loader.

The Buk-M1 (as well as the rejected Buk-1) uses SARH guidance similarly to 2K12 Kub. The fire control radar uses continuous wave (CW) target illumination. In fact the Buk-M1 is a scaled up and upgraded Kub with stronger and better jam resistant radar in addition with a larger and dual thrust rocket motor equipped missiles to have similar engagement range at med-low altitude to the predecessor 2K11 Krug.

Thanks to the camera on the TELAR the Buk-M1 (the camera is marked with red arrow above on the image) very likely is able to perform the same delayed CW target illumination as the 2K12 Kub-M3 with 3M9M3 missiles. For optical tracking target coordinates are provided by the target acquisition radar of the battalion the 9S18M1 Kupol-M1. The nominal maximal detection range of the Kupol-M1 against fighter size targets is about 140 km. The battery command post is the 9S470M1.

The brigade command post of the Buk-M1 functions as the CP of the brigade but it also serves as top level (army group) IADS element in army air defense. The 9S52 Polyana-D4 is more or less comparable to VS-11 Vozduh but is a fully mobile system. It can distribute data and establish connection not only between the batteries of the Buk-M1 but it coordinates the work of the S-300V and Buk-M1 brigade. Moreover it is able communicate with the Beriev A-50 AWACS airplane as well the homeland air defense system (5S99E Senezh and 73N6 Baikal-1E).[65]

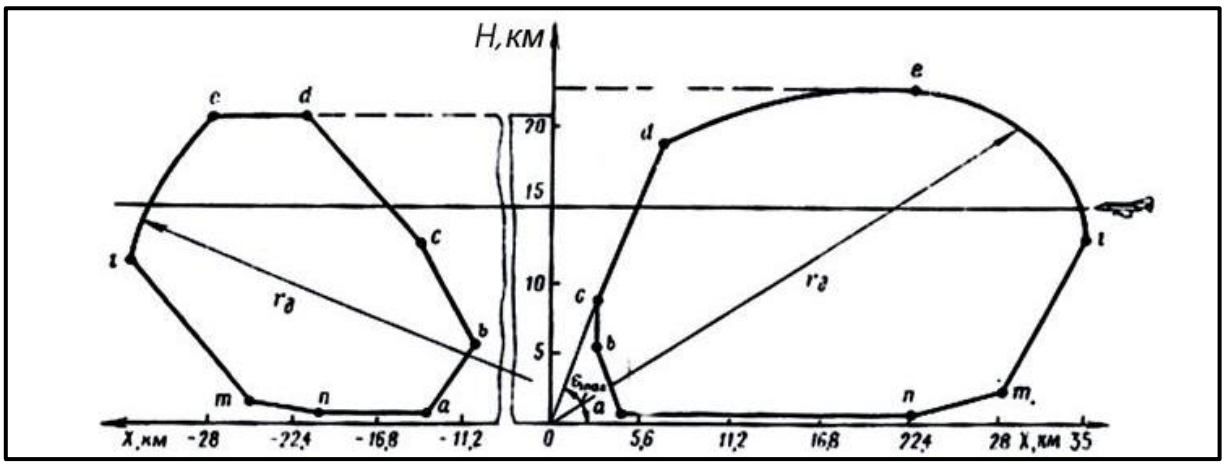
[65] https://ru.m.wikipedia.org/wiki/Байкал-1

Above left is the 9S470M1 battalion command post on right is the 9S18M1 Kupol-M1 target acquisition radar (SOC). On both vehicles are well visible the typical antennas for the digital datalink. It provides the connection within the battalion and between the 9S52 Polyana-D4 brigade command post.

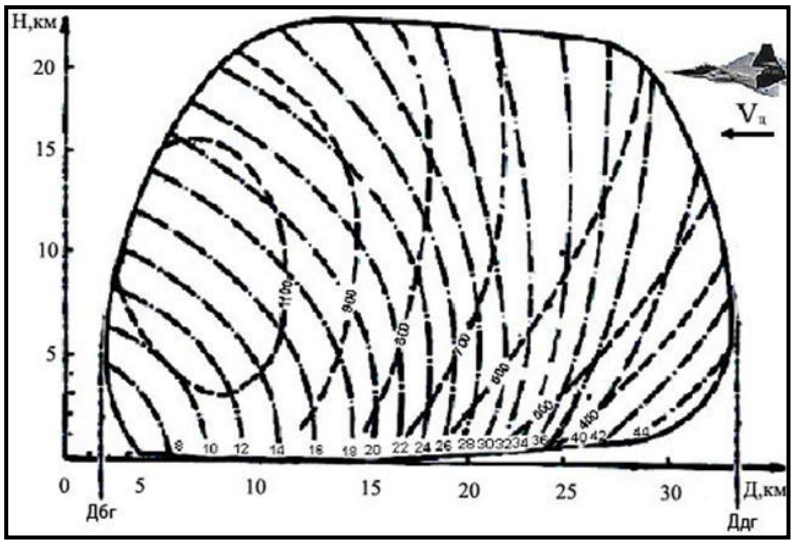
Above left the Polyana-D4 brigade command post, above right a picture from the inside the CP.

In a conflict between the NATO and Warsaw Pact Buk-M1 battalions very likely would deploy all along the frontline with overlapping engagement zone of the long range S-300V SAM system which demanded the better IADS connection and provided never seen before capabilities.

The appearance of the 9M38M1 missile is very similar to American RIM-66 Standard. This is not so surprising because both missiles were designed to the same role at least for the Russian navy. The maximal target speed of the system is 800 m/s, minimal target altitude is 15 meter, maximal altitude is 22 km. Minimal engagement range is 3 km the maximal is 35 km.

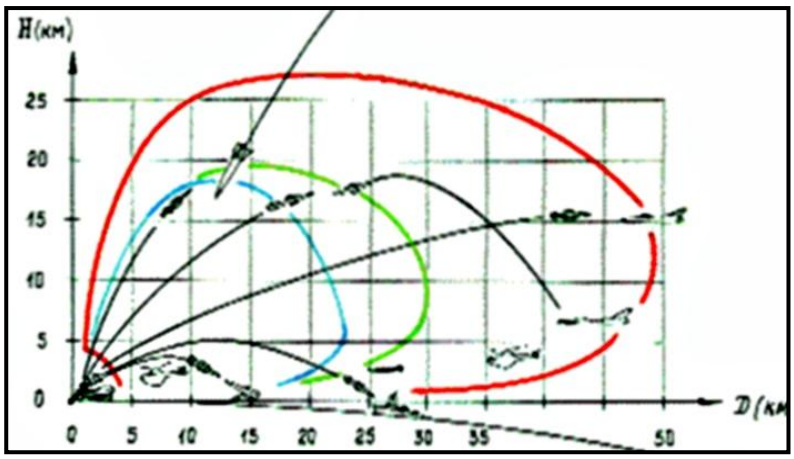


Engagement zone of the Buk-M1 with 0 km parameter (offset) distance against incoming (on left) and receding targets (on right.)



Engagement zone of the Buk-M1 with 0 km parameter (offset) distance against incoming targets.

The parametric curves shows the missile flight time and maximal speed of the target.



Engagement zone of the Buk-M2 with 0 km parameter (offset) distance against incoming targets.

The blue color shows the zone against ballistic missiles, the green against ARMs and the red against subsonic targets.

The boundaries of the zones against different target types correlate with the target speed iso lines on the diagram above.

It is remarkable 685 kg launch weight of the 9M38M1 missile is almost identical with 3M9M3 missile of the 2K12 Kub. While the engagement range is 60% larger and the warhead weight is increased to 70 kg from 57 kg. This huge leap forward is supported by the dual thrust rocket engine what provides better time-thrust characteristics for most of the trajectories. (Similar improvement was between the US-made AIM-7E and AIM-7F Air-to-Air missiles in range.) The average speed of the missile is about 850 m/s burnout speed is close to 1000 m/s.

The TELAR has only one target channel similar to Kub. The quantity of guided missiles is not limited any qty. can be launched on a single target because of the SARH guidance. With multiple launch is possible to increase the chance of a hit. Under the radome the TELAR is equipped with Cassegrain type radar antenna. The antenna is similar to the design of the radar of MiG-23 and MiG-29, see on the image right.

The Buk-M1 has anti-ARM capability as the Tor-M1. Against such targets the engagement zone is restricted and considerably smaller as well as the chance to hit (with one missile 0.9 against airplanes and 0.5 against ARMs and small cruise missiles, see later on the diagram). Officially Buk-M1 does not have ABM capability but Finnish crew during the final live fire exercise was able to shoot down the BM target imitator for the first attempt.

Comparing to the 2K11 Krug the capabilities and features of the 9K37 Buk-M1 totally outclasses the predecessor system. The defended airspace of the whole Buk-M1 brigade is similar or even slightly larger. The main differences are the maneuverability of the missiles as well the quantity of available target and missile channels. The anti-ARM capability is just the icing on the cake another remarkable feature. A Buk-M1 brigade has 2.6 times more target channels and 3.5 times more missiles on rails than the 2K11 Krug had.

Brigade target channel quantity:

• 2K11 Krug:	3 battalion * 3 battery * 1 SNR	9
• 9K37M1 Buk-M1	4 battalion * 3 battery * 2 SOU	24

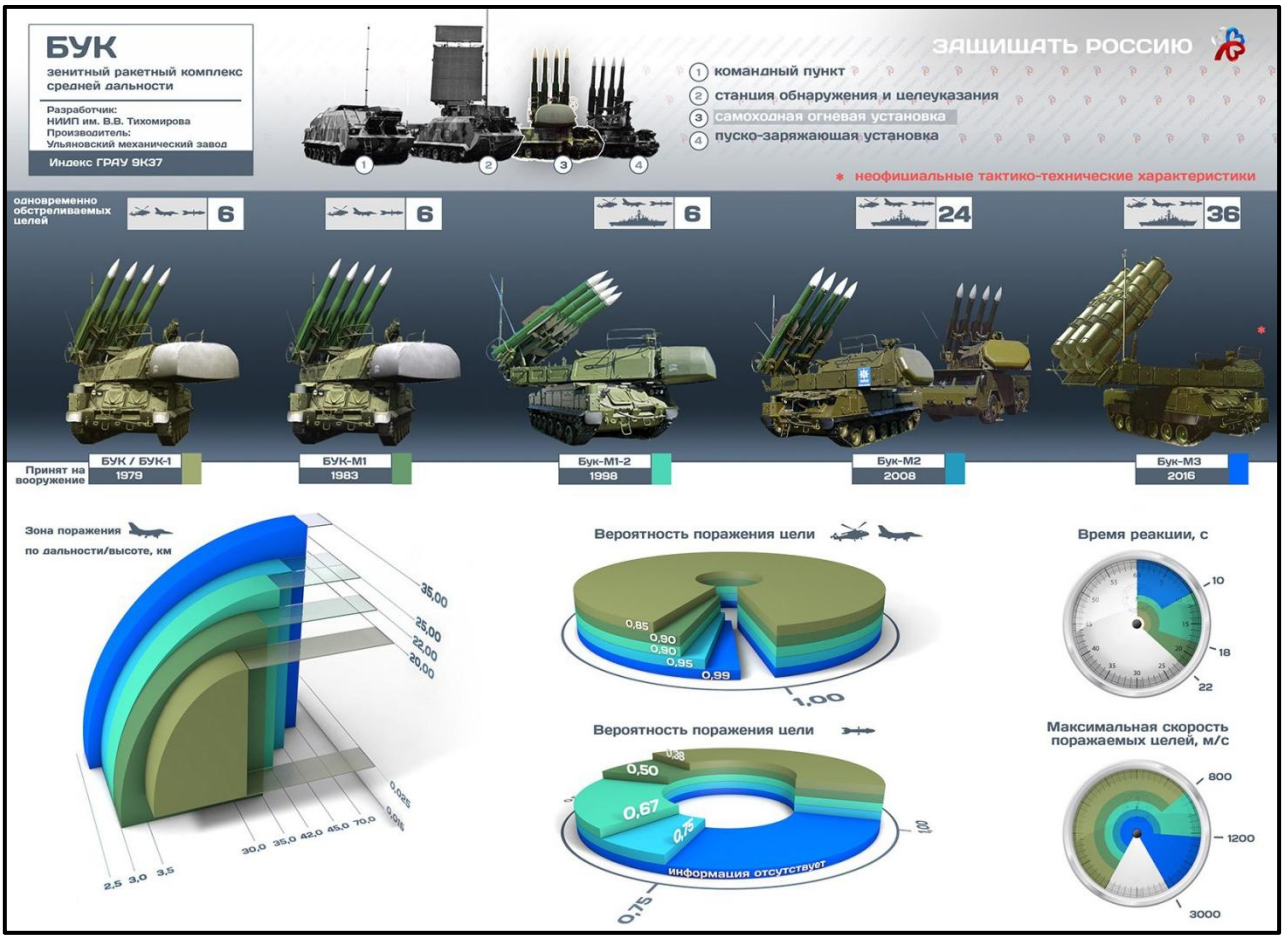
Brigade missile quantity on rails:

• 2K11 Krug:	3 battalion * 3 battery * 3 SPU * 2 missiles	54
• 9K37M1 Buk-M1	4 battalion * 3 battery *((3 SOU* 2 missiles)) + ((1 PZU* 8 missiles))	192

Of course the further development on Buk family was unavoidable but comparing to upgrades on other army air defense systems the capability increase is much more serious. Even the base missile family, antenna type and guidance also were changed during the process. This was possible because of the modular structure of the Buk.

From the Buk-M1-2 variant became available the 9M317 missile with slightly higher launch weight (720 kg) and the target speed increased to 1200 m/s. The minimal engagement altitude remained the same but the maximal distance increased from 35 km to 45 km, the maximal altitude from 22 km to 25 km. The maximal target speed makes more efficient against M3.0 top speed tactical ballistic missiles the M1-2. Of course against BMs the engagement zone is smaller only 20 km, maximal altitude in this case is 16 km. For ensuring the 90% or higher intercept success more than one missile is required.

Main parameters of different Buk variants. What is interesting on the image the available target channels because on a later image Buk-M3 has 36x and not 24x. This is maybe a typing error or just in the moment of the released material was not planned the ARH guidance. Maybe this is why M3 has the same value as M2.



Evolution of the Buk SAM family considering the TELARs, TELs and different types of missiles regarding on range and target parameters.

More serious upgrades were implemented for the 9K317 Buk-M2 and the 9K317M Buk-M3. For the M2 variant the CW radar of the TELAR is discarded to a planar array electronically scanned radar. The system very likely uses the same guidance method as the Tor-M1/M2, radio command guidance until the terminal phase SARH guidance or exclusively SARH. Because of the rapid scan capable radar a single Buk-M2 TELAR has four target channels instead one of the Buk-M1. The number of available target channels are quadrupled. The firing arc of a single TELAR is 90 degrees. The range of the upgraded 9S18M1-3R (export

variant) target acquisition radar increased to 150 km and the battalion CP vehicle is also the more advanced 9S510 type.

The Buk-M2 (as well as M3) has so many target channels which makes practically almost undefeatable with classical SEAD methods using only ARMs. The system has so many fire control radar – with 90 degree azimuth scan zone which means 90 degree firing arc – and so many target channels which makes hardly imaginable such a scenario where any opponent can launch enough AGM-88 or similar ARM to bypass the massive firepower of the Buk-M2.

Typically a fighter can carry two (F-16, Rafale, Tornado) or four (F-18E Super Hornet, Su-30 family, Eurofighter Typhoon) ARM considering reasonable weapon configuration. Because a single battery has 3x90 degree firing arc and 4x target channels in any direction literally it is the only way to suppress or destroy the Buk-M2 launching more ARMs then total missile inventory of the system which is 48 missiles per battery. We can judge how stong effort is needed to deal even just a single battery...

Of course the missiles of the Buk-M1/2/3 are not cheap therefore beyond a point economy is a factor. Is not necessarily has to shot down all incoming ARMs by the Buk. The slower but more numerous GBU-39/53 Small Diameter Bombs salvo also can be partially dealt by the Tor-M1/M2 or even the 2K22M Tunguska is able to this to save missile for larger range targets.

The improvements of the Buk-M3 are even more impressive and radical. One of the major change is the totally new 9M317M missile (on the image left) which is also used by the naval Stihl-1 SAM system.[66] The new missiles are stored in canisters and[67] the available missile for TELARs is increased to six.[68] The new missile can be SARH or ARH guided see later about the detailed explanation. The new 9M317 family still uses the butterfly shaped shrapnel what was developed for the M1 variant.

Thanks to the more optimal length/diameter ratio even with a lighter missile (581 kg) the engagement range is increased to 70 km, maximal target altitude is 35 km, maximal target speed is 3000 m/s. The very high target speed limit makes possible to shoot down theatre ballistic missiles up to about 3000 km range. With the active radar guided missiles the target channels per battalion is increased to 36.

This design change is very likely the result of experiences of the operation Allied Force. During the operation NATO air force was able to suppress (but no fully destroy) with large scale use of AGM-88 the Serbian SAMs because the old SAMs had only single target channel. With ARH terminal guidance the emission time of the TELARs can be reduced. Moreover if we assume appropriate datalink connection using TELARs is not necessary or just for very short periods. Therefore in some aspects the Buk-M3 with ARH guided missile is partially similar to NASAMS but with much larger engagement zone and ATBM (Anti-Tactical Ballistic Missile) capability. Or course Buk-M3 is much more expensive.

66 *It is bit funny that Buk-M1 started as a joint SAM system with strong opposition from the army and now the Buk-M3 also is a joint system with a new missile.*

67 *The Buk-M1 and M2 are the last SAM systems in the army which do not use canisters .*

68 *It is quite interesting how long it took get rid of rails while the Osa-AKM, Tor-M1, Strela-10 and 2K22 Tunguska have stored their missiles in canisters since decades. The rail launched missile archaic design feature long lived in Buk family but finally got this upgrade.*

The ATBM capability of the Buk-M3 means very likely it has full auto mode similar to S-350 Vityaz and the American Patriot SAM family. We can safely assume this feature because even the smaller Tor-M2 system has full auto mode. The reaction time of the Buk-M3 is also improved from 15-18 seconds of the M1 version to 8-10 seconds.

Above left is the new TEL of the Buk-M3 the 9A316M with 12x missiles, above right is the new TELAR the 9A317M with 6x missiles using canisters.

The low level target detection and engagement capability is also increased by a new radar. Similar to S-300P missile family the Buk-M3 can have a mast installed radar. This is the multi functional 9S36 Chair Back radar. The radar is able to illuminate targets for missile guidance and in case of need can perform sector search. The antenna is not rotatable only the direction (azimuth) setting of the mast can be changed.

The deployment time comparing to the 76N6 NVO (Clam Shell) low level target acquisition radar of S-300 is just a fraction because craning operation is not needed. The 21 meter tall mast is set up with hydraulically driven pistons. The successful live fire trials of the Buk-M3 happened in 2015.

9S36 Chair Back radar during deployment phase. On the right is the 9S18 Kupol target acquisition radar.

The main parameters of the Buk family are in the chart below:

Variant	*missile*	*weight*	*range*	*altitude*	*target speed*	*missile max. G*	*target channel per TELAR*
-	-	*kg*	*km*	*km*	*m/s*	*G*	
9K37M Buk-M1 (SA-11)	9M38M	690	3-35	0,015-22	800	19	1
9K37M Buk-M1-2 (SA-11)	9M317	720	3-42	0,015-25	1200	30	1
9K317 Buk-M2 (SA-17)	9M317M	720	3-50	0,015-25	1200	30	4
9K37M Buk-M3 (SA-17)	9M317MA	581	3-70	0,015-70	3000	30 (?)	6

Target channel quantity of a Buk brigade depending on the variant:

- 9K37M1 Buk-M1 4 battalion * 3 battery * 2 SOU (1) 24
- 9K317 Buk-M2 4 battalion * 3 battery * 2 SOU (4) 94
- 9K317M Buk-M3 4 battalion * 3 battery * 2 SOU (6) 144

Missiles ready to launch of Buk brigade depending on the variant:

- 9K37M1 Buk-M1 4 battalion * 3 battery * (2 SOU * (4) + 1 PZU * (8)) 192
- 9K317 Buk-M2 4 battalion * 3 battery * (2 SOU * (4) + 1 PZU * (8)) 192
- 9K317M Buk-M3 4 battalion * 3 battery * (2 SOU * (6) + 1 PZU * (12)) 288

Below is the short explanation for understanding the designation of the different type of the missiles.[69] Two different guidance (nose) section can be mounted. The 9E420 type has SARH guidance the 9V1103 (in Russian alphabet V = B) has ARH guidance. Missile with the SARH nose section has the letter 'A' in the designation. The letter 'E' means it is the export variant, the letter 'F' indicates the naval variant and the letter 'M' indicates canister loaded variant. These letters can be aggregated in the designation.

The following types exist according the source: 9M317, 9M317E, 9M317A, 9M317F, 9M317M, 9M317ME, 9M317MA, 9M317MAE, 9M317MF, 9M317MFE. The container/canister stored ARH guided missile of the Buk-M3 therefore is the 9M317MA in case of export variant 9M317MAE.

In short, the Buk-M1 and all the later variants represent a totally different level comparing to any other previous army or even PVO SAM systems. Every variants of the Buk family have exceptionally lots of target channels and missiles. Very likely the cost is the downside of the system. So far only a very few countries bought any variant of the Buk. Finland acquired just after the Cold War a small quantity of Buk-M1 in exchange of Soviet debt repayment. Some ex-Soviet countries bought or inherited small quantity M1 or M2 variant besides Syrian M2 order. (Finland already have replaced Buk-M1 with NASAMS 2)

The first full Buk-M1 brigade entered in service in about end of 1986 or early 1987. Typically the most advanced new equipment appeared first in East Germany but surprisingly the Buk-M1 appeared first in Hungary in the Southern Group of Soviet Forces while replaced the 2K11 Krug (SGSF, Южная Группа Войск).

69 https://vpk.name/library/f/9m317.html

Finland acquired three Buk-M1 batteries in 1995 counting in today's cost for about 200 million Euro (850 M Finnish markka). Russian offered even the most advanced and long range S-300V but Finland found it too costly even they were amazed of its features. Russian offered also the S-300PMU battery for 700 million Finnish markka cost of each 5V55R missile was 3M Finnish markka.

This pricing is a bit strange because the S-300PMU has only three radars (each are different type with longer range) but the missile quantity both offers were almost the same. The three Buk-M1 battalions in total had 18x TELARS and 3x Kupol radars.

According to Finnish sources the radar and guidance technology of the Buk-M1 is similar to 2K12 Kub but in general is more advanced. According to Finnish operator the jam resistance of the Buk-M1 was quite goon in its era.

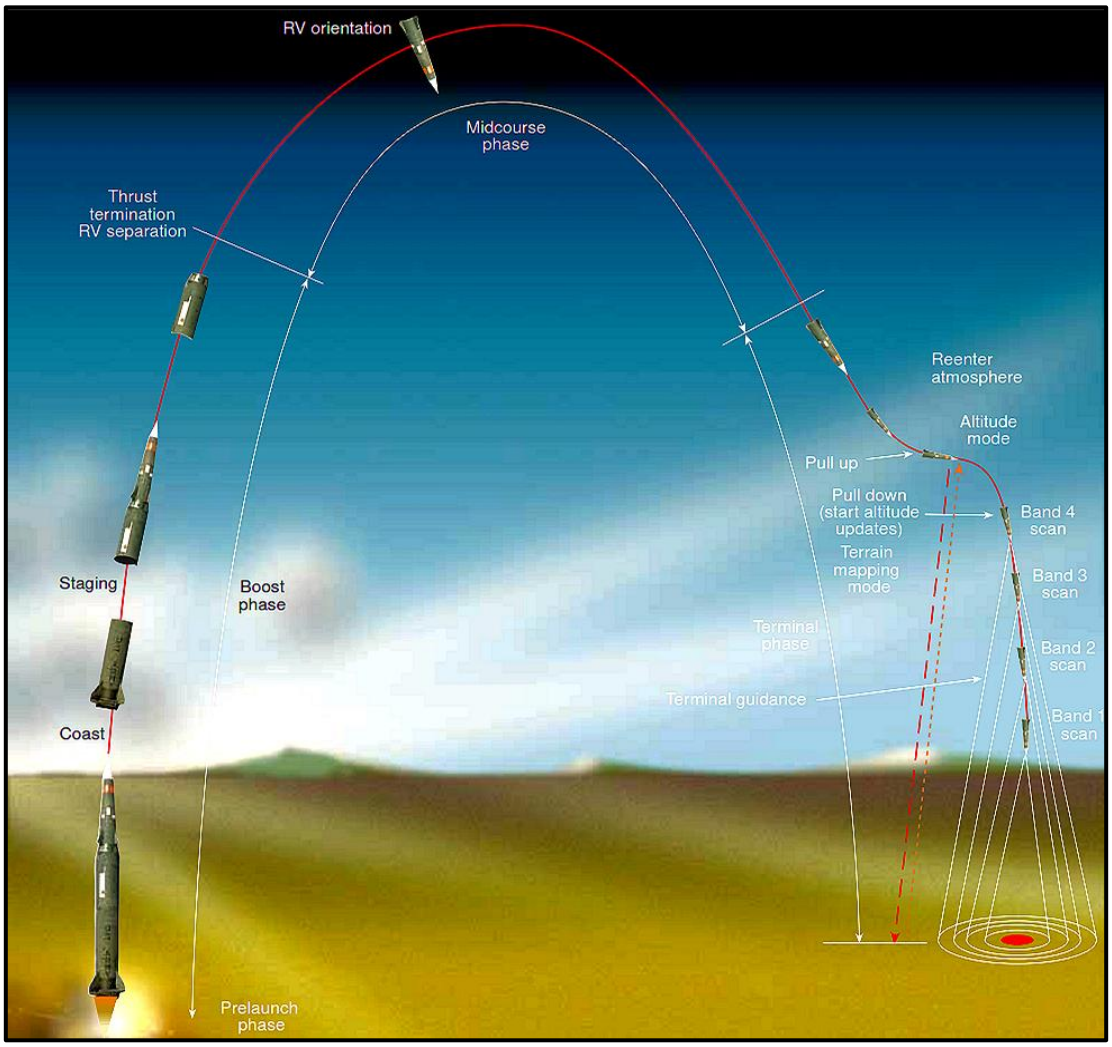
The Buk-M1 is similar to American AEGIS system which uses also many CW illuminators to establish more than one target channels per ship. On US ships are also separated target acquisition radar which assigns the target from CW illuminators.

As usual finally are some videos and about the system:

http://www.ausairpower.net/APA-9K37-Buk.html
https://www.youtube.com/watch?v=LSXMhaFntrU
https://www.youtube.com/watch?v=t1LQWFul2UE
https://youtu.be/l115fJpCIfc
http://nevskii-bastion.ru/buk-m3/

9K81-1 Sz-300V1, 9K81 Sz-300V (SA-12A/B Gladiator), 9K81M Sz-300VM (SA-23 Giant)

The S-300V family is the queen of the army air defense system considering both its engagement zone and maximal speed of the targets. The Buk-M1 in the late '80s had extraordinary capabilities but the S-300V put the bar even more higher. During its design was a very high priority the ABM capability. Not only against tactical ballistic missiles (up 300 km range) but even against Pershing 1a and II[70] advanced intermediate range ballistic missiles (IRBM) were considered a threats. The Mach 6-8 target speed with terminal phase maneuvering capability (similar to Soviet OTR-23 Oka) meant extremely difficult task. In addition the whole system had to be fully mobile with ABC protection. For the development of the 9K81 S-300V the NII-20 (GKOT) design bureau leaded by V. P. Efremov was appointed . He was the chief designer of the Krug (SA-4) and Osa (SA-8) systems.



Attack profile, target search and identifying capability of the Pershing II ballistic missile.

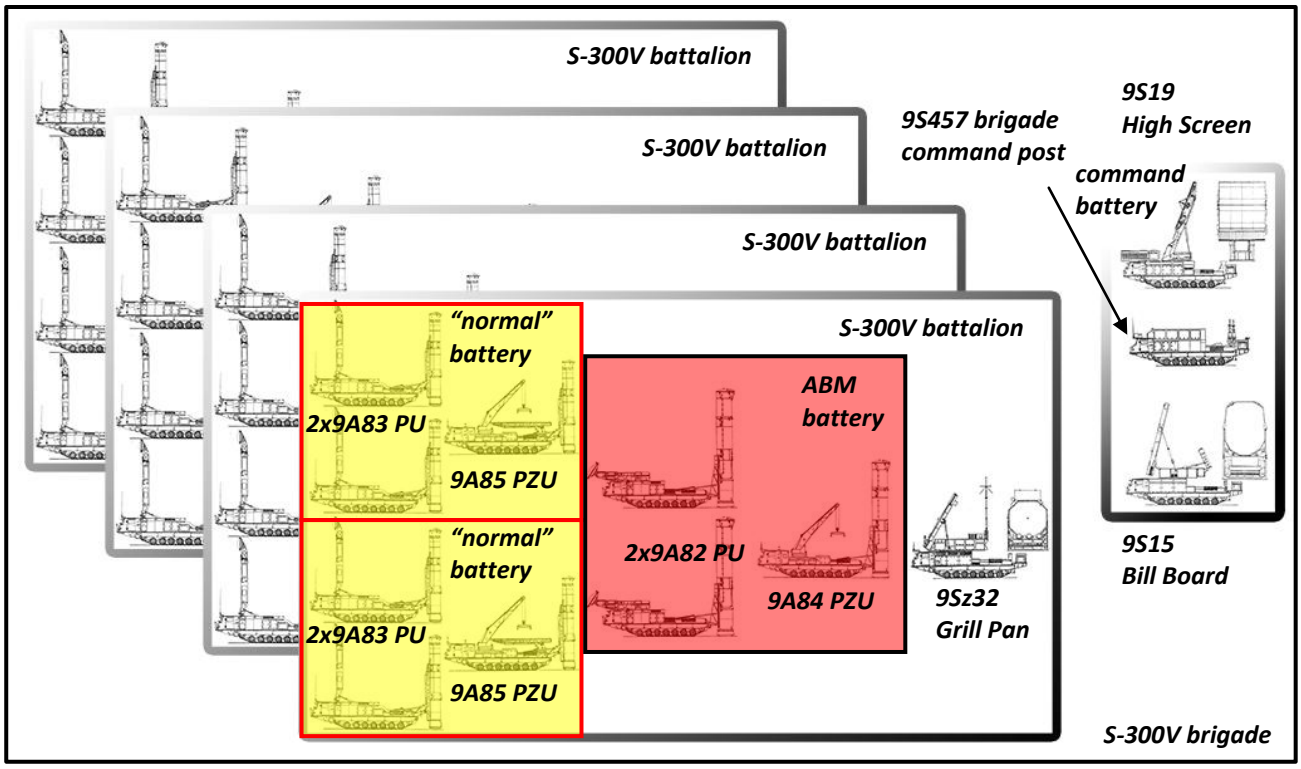
On the Internet fans of Russian technology sometimes make such overstatement that the later designed 9K720 Iskander or the OTR-23 Oka ballistic missile "practically cannot be downed". This is quite an interesting statement while against such targets was designed the S-300V. 20+ years before the current ABM systems. In fact as we can judge the publicly available information the Pershing II was even more advanced and difficult target than the OTR-23 Oka. So if such targets as Iskander "cannot be downed" why was designed the S-300V and why is considered as success? Both cannot be true...

[70] https://en.wikipedia.org/wiki/MGM-31_Pershing , https://en.wikipedia.org/wiki/Pershing_II

The long and delayed development of the S-300V system was one of the indications the more and more limited resources of the Soviet Union because of economic issues. Similarly to the 9K37 Buk family the first initial variants of the Gladiator entered in service with restricted capabilities and only with minimal quantity. Regardless the S-300V designation is very similar to S-300P SAM family for the PVO they are not related in any way. They are totally different "species". Some of the equipment have similar appearance because of the same working principle of the radars (electronically scanned radars) but the vehicles, the missiles and the guidance are totally different from the S-300P/S-400 family.

The S-300V1 variant entered in service without the dedicated ABM battery. The engagement zone of a battalion was "only" 75-100 km depending on the type of the target. The kinematic range of the missiles are much higher than these figures because of the very high burnout speed. The case is exactly the same as the evolution of the S-300P family. The later developed upgraded variant now can utilize the kinematic range of the missiles.

Until end of the Cold War the S-300V variant entered into the service the development S-300VM (V4) could be finished only about 20 years later after the Cold War. (Thanks to the high oil prices in the 2000s).



One S-300V brigade with four battalions, each battalion with two "normal" and 1x ABM battery.

The main elements of the S-300V brigade are the following, let's start with the commanding battery:

The ***9S457 KP*** brigade command post (командный пункт). It does the prioritization the engagement by using the acquireddata of the 9S15 KO Ozbor-3 target acquisition radar. It sorts targets for each battalion. Also the CP's task to establish the datalink connection between the brigade and the Polyana-D4 command post of the Buk-M1 brigade.

The CP is able to track 200 targets, triangulate 70 jamming targets,[71] prioritize 24 targets for engagement. The detection and prioritization time is 3 seconds against incoming IRBM (Pershing-II).

Crew of the CP is three officers which indicates high level of automatization similar to American Patriot. Considering the level of solid state electronics industry of the Soviet Union likely this could be one of the major factor of the delayed development. The weight of the CP is 39 tons.

The target acquisition radar of a brigade is the ***9S15 KO Ozbor-3*** (Bill Board), (РЛС кругового обзора). It provides the long range situational awareness around the brigade. The radar operates on 10 cm wavelength, in azimuth is mechanically scanned (rotation) in elevation is electronically scanned. The antenna uses 1.5x1.5 degree pencil beam. Crew of the radar is four officers the weight of the system is 46 tons. The radar has the following operational modes:

1st mode:

- 0-45 degree electronic scanning in elevation
- 360 degree mechanical scanning: 12 sec
- Maximum displayed detection range: 330 km
- Detection range of a fighter size target: 24 km

2nd mode:

- 0-20 degree electronic scanning in elevation
- 360 degree mechanical scanning: 6 sec
- Maximum displayed detection range: 150 km
- Detection range of a fighter size target : 150 km
- Detection range of a SCUD size missile: 115 km
- Detection range of an MGM-52 Lance size missile: 95 km

3nd, sector search mode:[72]

- 0-55 degree electronic scanning in elevation
- ±60 degree electronic scanning in azimuth
- Total scan time to a set direction: 9 sec
- Maximum displayed detection range: 150 km
- Detection range of a fighter size target: 150 km
- Detection range of a SCUD size missile: 115 km
- Detection range of an MGM-52 Lance size missile: 95 km

[71] *It is performed likely with the datalink using the data from Buk-M1 brigades well of Grill Pan radars. Performing with radars of the command battalion seems unlikely because they are too close to each other. The bearing difference is too small for the process. Another reason is the role of the 9S19 PO radar. If that just for 30 seconds does not search BM targets during this time a Mach 8 speed ballistic missile flies 75 km. This is an unacceptable unutilized search time of the dedicated ABM radar for such a feature.*

[72] *Likely this is just a backup mode in case of the failure and loss of the 9S19 PO Imbir (High Screen) ballistic missile search radar. If the Ozbor-3 radar is used in sector search mode the brigade loses the long range 360 degree target acquisition capability. In this case it has to rely on other sources via datalink.*

The 3D ABM acquisition radar of the brigade is the ***9S19 PO Imbir*** (High Scren), (РЛС программного обзора). The radar operates on 3 cm wavelength (10 GHz), both in azimuth and elevation is electronically scanned. The antenna can be set any direction to set the monitored zone but it provides only sector search capability. The radar is not rotated during its operation.

The antenna uses 0.5x0.5 degree pencil beam. Crew of the radar is four officers, the weight of the system is 44 tons. The radar has the following operational modes (scanning within 12,5-14 seconds):

1st mode against Pershing II:

- Electronic scanning 26-75 degree in elevation
- Electronic scanning ±45 degree in azimuth.
- Maximum displayed detection range: 175 km

2st mode against AGM-69 SRAM:

- Electronic scanning 9-50 degree in elevation
- Electronic scanning ±30 degree in azimuth
- Maximum displayed detection range: 175 km

3st mode against air launched cruise missiles and stand-off jamming aircraft:

- Electronic scanning 0-50 degree in elevation
- Electronic scanning ±30 degree in azimuth
- Maximum displayed detection range: 175 km

The main elements of an S-300V battalion are the following:

The ***9S32 SNR*** (Grill Pan), (многоканальную станцию наведения ракет) is the fire control radar of the battalion. It guides the missiles until terminal phase CW illumination which is provided be the TELARs.

The Imbir is capable of tracking 6x targets and 12x missiles. The radar operates on 3 cm wavelength (10 GHz), both in azimuth and elevation is electronically scanned, it uses 1x1 degree pencil-beam.

The antenna can be set any direction to set the monitored zone but it provides only sector search capability. The radar is not rotated during its operation. Crew of the radar is six officers, the weight of the system is 44 tons. The radar has the following operational modes:

1. CU (ЦУ), target acquisition received from the 9S475 KP. Electronic scanning 6 degree in elevation and 5 degree in azimuth around the target. It means around the tracked targets a ±3 and ±2.5 degree zone is scanned which makes possible to detect the launched ARMs from target targets besides the target acquisition capability of the *9S15 KO Ozbor-3* (Bill Board). [73]

2. Tracking missiles with 1x1 degree pencil beam. For missile guidance both of 1st and 2nd mode are needed.

3. AR (автономная работа), autonomous target acquisition. Electronic scanning 0-18 degree in elevation and ±30 degree in azimuth. In fact this is sector search mode. [74] Detection range against different type of target are the followings:

    - Detection range of a fighter size target: 150 km
    - Detection range of a Pershing size missile: 140 km
    - Detection range of a SCUD size missile: 90 km
    - Detection range of an MGM-52 Lance size missile: 60 km

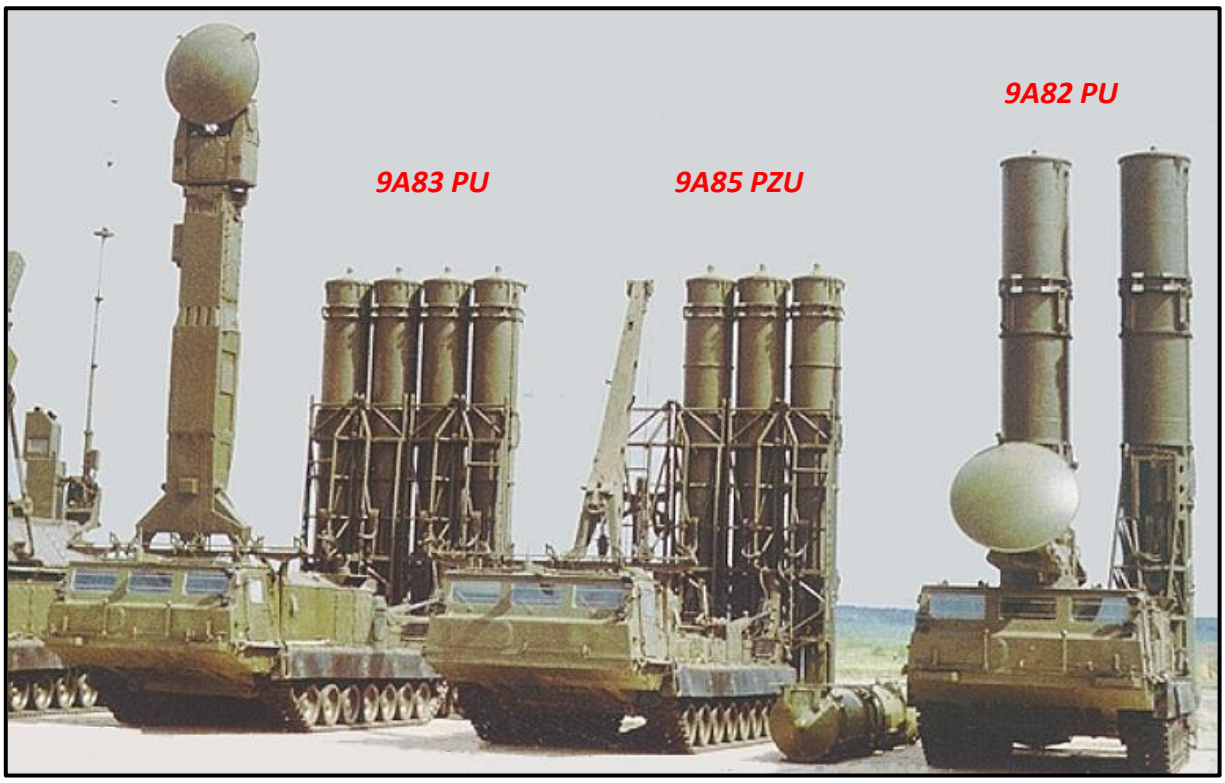
The battalion has two different types of batteries the normal and the ABM battery. Each battery type has two different kind of TELAR and TEL vehicles.

The normal battery has two 9A83 PU (TELAR, пусковая установка) with 4x 9M83 missiles, each TELAR has its own target CW illuminator. The crew of the TELAR is three officers. The guidance uses CW illumination in terminal phase. The moment of the CW illumination is determined by the 9S32 SNR (Grill Pan) radar. Each TELAR can track and illuminate only a single target but as usual the CW SARH terminal guidance makes possible to guide as many missile on a single target as wished but practically only two per target. A normal battery has 2x target channels. Similar to Buk-M1 system the 9A85 PZU (TEL, пускозаряжающие установки) acts as a launcher and as well as a loader for PU vehicles. Reloading time of four missiles is 60 minutes.

The composition of the ABM battery is almost identical to the normal battery just uses different hardware. It also has 2x target channels. The TEL is the 9A82 PU but has two larger 9M82 type missiles. The crew of the 9A82 is also three officers. The loader vehicle is the9A84 PZU. The vehicles are on the image below (except one.)

[73] *Which it makes very similar to fire control radar of S-300P the 30N6 RPN (Flap Lid) considering the tracking capability of the radar either.*

[74] *Likely this is just a backup mode for "just in case" if there in not datalink connection with the brigade CP or with any other high level unit. It is not clear to me the availability of direct link between the S-300V battalion and the Polyana-D4 or the 9S457 brigade CP is necessary for the communication.*



On the left is the 9A83 PU launcher (TELAR), on the middle is the 9A85 PZU missile loader and launcher (TEL), on the right is the 9A82 PU ABM launcher (TELAR). The 9A84 PZU is not on the image but it looks similar to 9A85PZU but it has only two larger missile canisters as the 9A82 PU.

The basic element of the S-300V brigade is the battalion because of the 9S32 SNR (Grill Pan) radar. Regardless the composition of an S-300 battalion looks similar to Buk-M1's battery the situation is different. In theory with limited capability and with IADS datalink the batteries of the Buk-M1 are combat capable because only the TELARs are needed to guide missile. The 9S18M1 Kupol radar technically is not needed. In contrary for S-300V both the TELARs and the Grill Pan radar are needed because of the combined RCG + SARH CW terminal phase guidance method.

The 9S32 SNR Grill Pan illuminates and tracks target similar to the S-300P system but in terminal phase CW illumination is required by the TELARS (9A83 and 9A82 PUs). Without the Grill Pan radar a battalion does not have any combat capability. In case a TELAR fails or is destroyed only a single target channel is gone. The RCG signals are provided by the Grill Pan radar because it is the only unit which tracks both the targets and missile before the terminal phase. At the end of the ballistic interception phase the missiles swaps to CW SARH guidance. During the whole engagement the Grill Pan radar tracks the target to determine the success of the engagement.

The SNR (Grill Pan) can track 6x targets and 12x missiles simultaneously which are enough to for the 6x available target channels of a total battalion even if two missiles are guided on each targets. Comparing to American Patriot much less missiles can be on the way towards to targets regardless the much more complicated system with many radars. **But for exchange the maximal target speed is far beyond the capabilities of the contemporary variant of the Patriot**.

If we look and compare well the AEGIS system and the S-300V we can see how similar they are. The main difference that AEGIS is installed on large destroyers or missile cruisers. Because of the platform it has 360 engagement degree capability if we consider the ships as single missile battery. In terminal phase for not active radar guided missile the AEGIS also uses independent CW illuminators just as the S-300V.

If the S-300V had four Grill Pan radar it would have 360 degree engagement zone. Because of the NATO vs WPACT geography the 360 degree engagement zone was pointless. The designers could be sure about the main threat direction of missiles. Of course the Grill Pan can be turned any direction but its azimuth scan limit restricts the engagement zone in a given engagement situation. While the AEGIS system in the same time can engage targets in 360 degree zone. We can say S-300V is a land based mobile, partially downscaled AEGIS. See later the description of the AEGIS system is the Naval Air Defense Chapter.

The S-300 has two types of missiles the larger and heavier 9M82 and smaller 9M83. The missiles have two stages. The main difference between them is size of the booster stage. The 9M82 ABM missile has larger section with about 5 seconds burn time, the second stage burn time is 14 seconds. The burn time of the second stage is almost the same for both missiles. The point or larger booster stage for the 9M82 to provide much more acceleration for the ABM role.

The missiles use combined RCG + terminal SARH CW guidance by the PU vehicles. Before 3-10 seconds the impact switches the missiles the guidance method depending on the type of target and the jamming. The main parameters S-300V family are in the chart below:

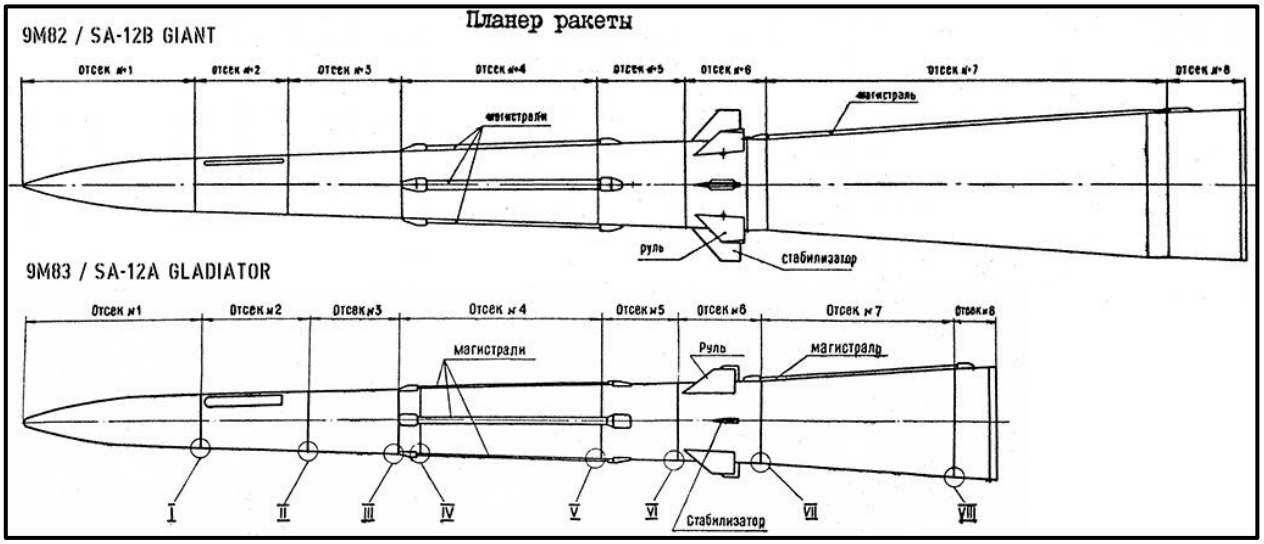
Type	*Missile*	*Missile weight*	*Rage*	*Altitude*	*target speed*	*missile overload*	*burnout speed*
-	-	*kg*	*km*	*km*	*m/s*	*G*	*Mach*
9K81 S-300V (V2) (SA-12A/B)	9M83 9M82	2290 4685	75 100	0,025-30 0,025-30	1700 3000	20	3,62 5,4
9K81M S-300VM (V4) (SA-23)	9M83M 9M82M 9M82MD	2290 (?) 4685 (?) ?	120-130 200-250 350	0,025-30 0,025-30	1700 3000 4500	30	5,14 7,85

The engagement ranges above concern against airplanes but as we can see on the on target speed the S-300V family has ABM capability against different range of BMs.[75] These capabilities were reached incrementally by the V1, V2 (these two are the plain 'S-300V' variants) and finally by the V3 and V4 (VM).

	S-300V1 (SA-12A)	*S-300V2 (V) (SA-12B)*	*S-300VM (V3) (SA-23)*	*S-300VMD (V4) (SA-23)*
IOC	*1983*	*1988*	*2013*	*2015 (?)*
maximal range	*75 km*	*100 km*	*200 km*	*350 km*
maximal target speed	*1700 m/s*	*3000 m/s*	*4500 m/s*	*4800 m/s*
maximal range against tactical/theatre ballistic missiles	*40/- km*	*30/40 km*	*30/40 km*	*30/40 km*
max. range of the targeted BM	*300 km*	*1100 km*	*2500 km*	*2500 km*

[75] 300 km BM range = 1700 m/s target speed
1100 km BM range = 3000 m/s target speed
2500 km BM range = 4500 m/s target speed

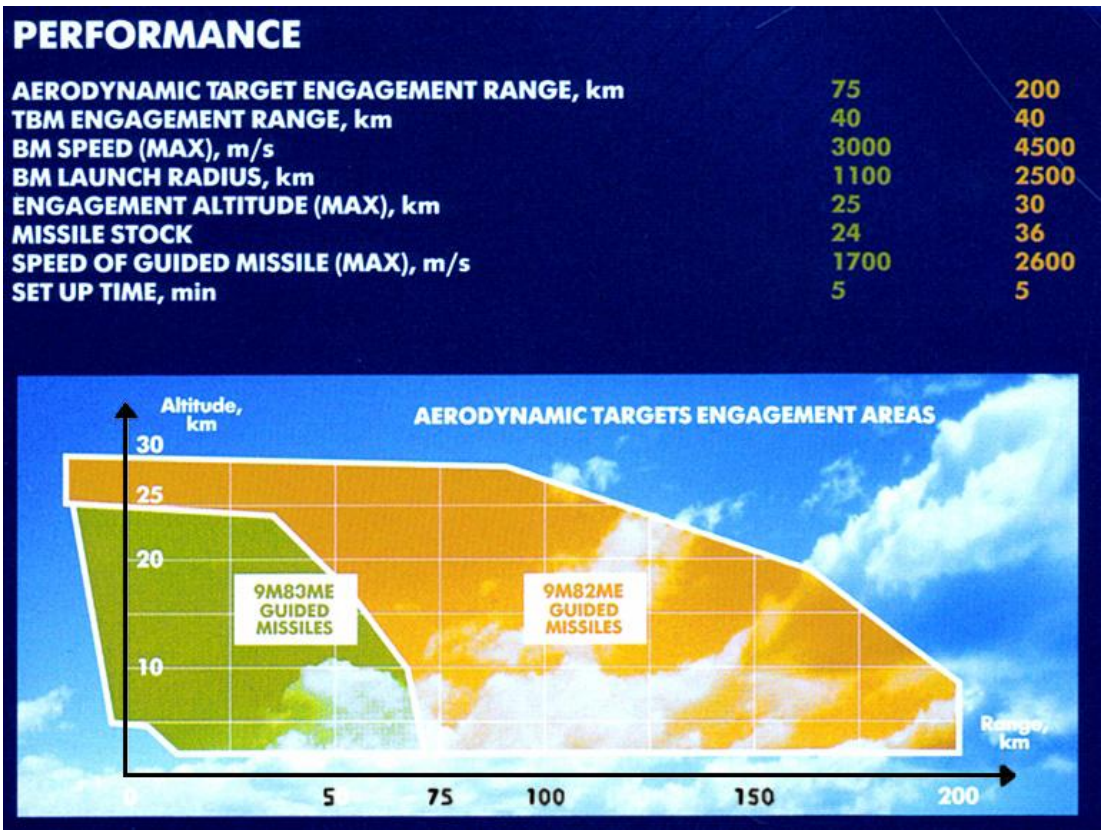
The weight even of the 9M83 missile is higher than any missile of the S-300P family. It is about 400 kg more heavier. The 9M82 is even heavier with 4.6 tons launch weight. It weighs twice as much as the 1.9 ton 48N6DM missile of the S-400 while it has similar range to it (250 km). The key is the speed of the missiles. The average speed of the missiles of S-300V is higher which increases the engagement zone against BMs. Even with such large speed the engagement range against BMs are just fraction comparing to subsonic airplanes or cruise missiles.



The larger and smaller 9M82 and 9M83 missiles. Their booster stages are different.

Above is the 9M82 missile. The man standing next to the missile gives a good view about the size. The length of the 9M82 is almost 10 meters with 1.2 meter maximal diameter.

The engagement envelope diagram below is a bit inaccurate because it shows the range of V1/V2 variant against airplanes in the green zone. While in the yellow zone shows with V3/V4 variant with upgraded missiles but only with the 9M82 missiles without the 9M83M which has only 120-130 km range. The ABM missiles of course can be used against airplanes. This is why the 9M82M determines the maximal engagement range against subsonic targets regardless it is the best ABM.



Engagement zone of the S-300VM

An S-300V battery has:

- 6x 9M82 ABM missiles with 2x ABM target channels
- 24x 9M83 missiles with 4x target channels against airplanes (and smaller range ballistic missiles)

S-300V brigade has:

- 24x 9M82 ABM missiles with 8x ABM target channels
- 96x 9M83 missiles with 16x target channels against airplanes (and smaller range ballistic missiles)

Following the end of the Cold War the S-300V was offered for export to anybody. During the Cold War was not an of option exporting such and advanced SAM system. Comparing to success of S-300P/S-400 the S-300V acquired so far only very limited success on the market. Until this day (2019) only Venezuela and Egypt bought it. It was offered for Finland in 1995 but they found way too costly (and overkill) the system comparing to their needs. All previously manufactured variants in Russia have been upgraded to VM (V4) configuration.

As of today (2015), in Google Earth only less than a half dozen S-300V brigades can be identified.

- Kaliningrad, Gvardeysk
- Ukraine, Uman
- Armenia, Gyumri
- Moscow, Naro-Fominsk
- Far East, Tavrichanka

As usual finally are some videos and images about the system:
http://www.ausairpower.net/APA-Giant-Gladiator.html
https://www.youtube.com/watch?v=AOz7f182Pc4
https://www.youtube.com/watch?v=IAUXkIWOuR4

Regardless the different political environment the lobby and rivalry between the design bureaus in even the Soviet Union was a thing. This is leaded to the Buk-M1, S-300P family and for the S-300V.

During the '70s the army, the navy and the homeland air defense had different threats which was important for them.

The army needed protection against Pershing II and other ballistic missiles.
The navy needed protection against sea skimming ASMs such as AGM-84 or Exocet.
The PVO needed a new SAM against low level cruise missile such as the BGM-109 or the AGM-86 ALCM. The new SAM was intended to replace eventually all the previous SAM systems.

These were the major threats and neither of the different branches cared about the threats of the others. Because of the strong political pressure from D.F. Ustinov[76] the army had to accept the same system as the Navy. This leaded to the Uragan system which later got the designation the 9K37 Buk-M1 from the army.

Before the 9K81 S-300V and the 9K37 Buk-M1 on army and army group level was used the same 2K11 Krug. Because of the pressure only the army group could get the S-300V. This happened because of the connection and good relation between different design bureaus and branches of the armed forces.

The 9K33 Osa was developed by the NII-20 (GKOT) which had good relation with the army and the Osa also was applied on ships. Also the NII-20 developed the 9K81 S-300V. Only the army uses exclusively the S-300V but they have to adopt also the Buk-M1. For acceptable ABM range the S-300V was needed a two stage missile which did not want the PVO. This is why unique the S-300V and means a lot the 'V' in its designation.

The 9K37 Buk-M1 was developed by the NII-10 GKRE bureau which had good relation with the navy. The army was forced to adopt the Buk-M1 but "for exchange" it got the S-300V.

The S-300P/F developed by the KB-1bureau which had good relation with the PVO. The largest navy ships got as a new generation air defense the S-300F on the smaller ships naval version of the Buk-M1 was installed. Therefore the KB-1 also got it share from the pie...

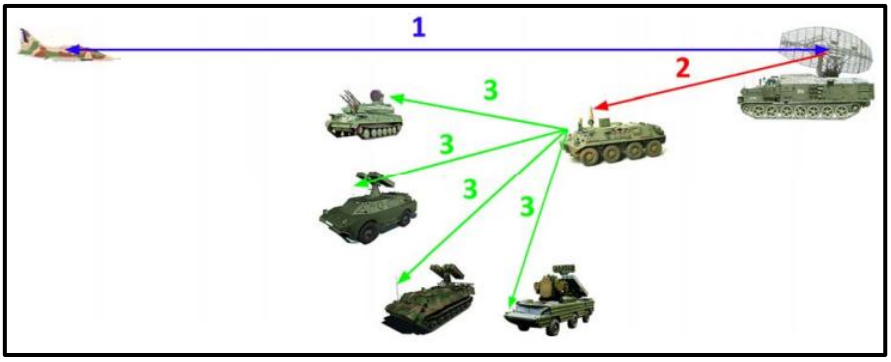
[76] https://en.wikipedia.org/wiki/Dmitry_Ustinov

IADS equipment of the army air defense

Similar to homeland air defense units coordination is required to make more effective the firepower of the army air defense. The task is difficult because the SAM and AAA units are mobile in addition the environment is much more dynamic comparing to static homeland air defense. Today the coordination can be ensured even from the highest level, long range army group level S-300V category SAM down to the MANPAD equipped infantry either. During the Cold War IR/radar SHORAD and AAA units – Strela-1/10 (SA-9/13), Osa (SA-8) and ZSU-23-4 Shilka – had different kind of IADS support.

Not only the quantity and quality of air defense units but also the available IDAS equipment was very different between the Soviet Union , the NSWP countries and other 3rd World country operators. In NSWP countries each regiment had one 9S482 BTR-60 PU-12 mobile air defense command post. (Nominally each regiment had two air defense platoons, see in the summarizing chart in structure and organization part).

The 9S482 Mobile Air Defense Command Post was based on the BTR-60 armored personnel carrier. The turret was replaced by a telescopic antenna (16 m max height) giving 25-30 km range. Inside the BTR vehicle an air defense command station was added.



1. Division-level radio technical troops detect an incoming target.
2. The target coordinates are sent to the 9S482 BTR-60 PU-12 via digital datalink channel
3. Target information is transmitted to the ZSU-23-4 Shilka, 9K33 OSA (SA-8 Gecko), 9K31 Strela-1 (SA-9 Gaskin), or 9K35 Strela-10 (SA-13 Gopher) batteries via radio (voice channel) which can prepare to the target engagement.

Even with this slow method comparing to fully digital datalink channel the units can work much quickly. The time of the search and target acquisition is spared and/or lowered. The 9K33 Osa-AKM could engage targets without turning its target acquisition (SOC) radar which is a very useful thing in case of AGM-88 and SEAD activity. (The wavelength of the SOC is inside the capability of the AGM-88 HARM.) The BTR-60 PU-12 was capable to establish datalink with P-15, P-18, P-19 radar and with the P-40 complex.[77]

[77] *The listed radars are the target acquisition radars of homeland air defense (SAMs) In the army the divisions had radio technical units. Besides them every 2K11 Krug (SA-4) regiment/brigade also had one P-40 complex with one 1RL128 and one PRV-16 heightfinder radar which was assigned to the army. The 2K12 Kub regiments also had the P-40. These provided the data for the BTR-60 PU-12.*

Because of the delay and limited capability of the voice channel it was a goal to improve the “bandwidth” the IADS. For this purpose was designed the PPRU-1 SOC battery command post with much more advanced capabilities. The PPRU-1 used the OVOD-M-SV (Dog Ear) X band radar for target acquisition therefore the command post is not solely dependent from higher level radars. At shorter range the command post can provide situational awareness and target coordinates for the air defense vehicles. The nominal detection range against fighter size target is about 80 km. The PPR-1 can support three platoons which means it can feed target coordinates the 1+1 platoon of ZSU-23-4 (with four vehicles) and Strela-10M (also with four vehicles) and the four 9K33 Osa-AK/AKM vehicles which are assigned to regiments (reserve battalions does not have air defense).

The PPRU-1 was used exclusively by the Soviet Union the NSWP countries had only the 9S482 PU12 command post. The more advanced M1-2 variant of this vehicle uses the VNIIRT 9S80M1-2 X band radar. [78]

The successor system of the PPRU-1 is the 9S80M1-2 Barnaul-T.[79]

It is quite interesting the evolution line of the PU-12 is still kept alive the latest iteration is the PU-12M7[80]


Above left is the PPRU-1 M1-2 command post in 2007 at MAKS exhibition above right is the Cold War variant of the system with analogue radar.

The 9S737 Ranzhir-M[81] is capable to feed with target coordinates for 4x Tor-M1 and 6x Strela-10M2/3 or Tunguska-M via digital datalink instead radio voice communication. The purpose of the 9S737 Ranzhir-M is the same as was with PPRU-1 but instead 4+4+4 for 4+6 vehicles because 6x2K22M Tunguska-M replaced the 4+4 Strela-10M and ZSU-23 Shilka. (Not in every regiments, Strela-10M3/4 are still in service 2019).

The Ranzhir-M is clearly a post-Cold War equipment it was not prepared to command as many vehicles what was necessary before the 2K22M. Comparing to the PPRU-1/Barnaul command post the later Ranzhir-M system does not have its own radar it relies on higher level target acquisition radars and datalink.

78 http://www.almaz-antey.ru/en/catalogue/millitary_catalogue/1220/1327

79 http://roe.ru/eng/catalog/air-defence-systems/barnaul-t/
http://www.npp-rubin.ru/index.php?itsfltinside=1&fulnro=38&thisissx=zuzzzla&lang=en

80 http://roe.ru/eng/catalog/air-defence-systems/pu-12m7/

81 http://roe.ru/eng/catalog/air-defence-systems/air-defense-automated-command-and-control-systems/ranzhir-m1/
http://pvo.guns.ru/asu/ranzhir.htm ,http://pvo.guns.ru/asu/ranzhir-m.htm

Above left is the 9S933, above right is the 9S935.

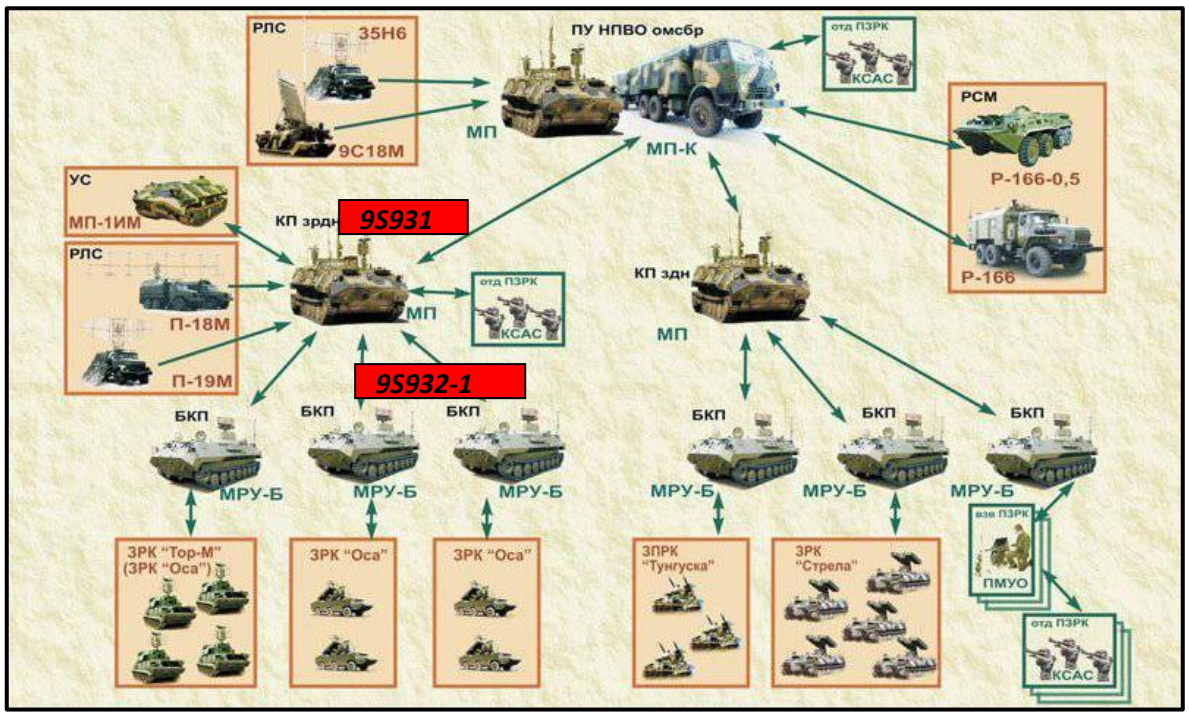
Today the even for MANPAD carrier crew is possible to provide target coordinates from higher level radars using small size portable displays such as the 9S933. Moreover with night vision sights and optics (9S935) it is possible to provide information. Similar to HUDs for the MANPAD operator bearing and or even heading of the target can be displayed which makes possible to launch missile even at night. [82]

(This feature is also mentioned at the description of the 9K35 Strela-10M)

The Cold War era variant of the 9S737 and its interior.

On truck is the 9S737M the interior shows this is the latest variant of the system. Of course tracked variant is also available of the command post.

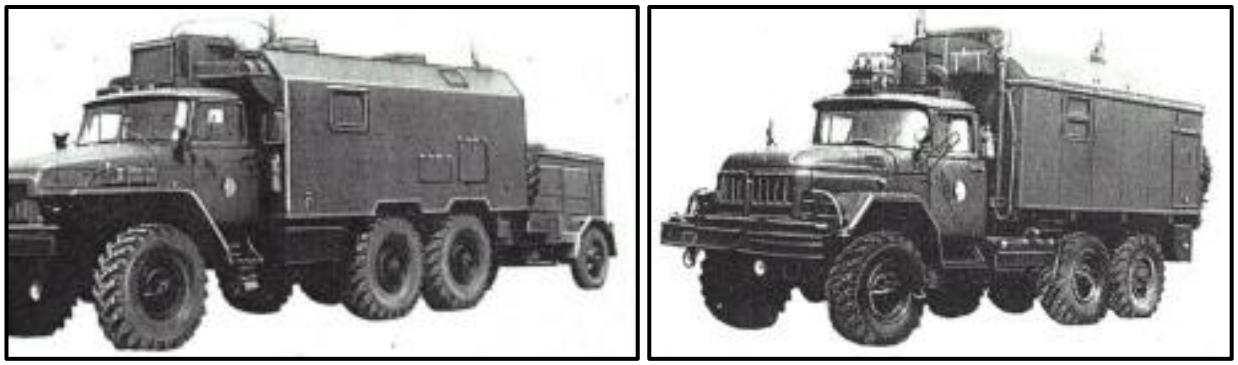
82 http://www.npp-rubin.ru/index.php?itsfltinside=1&fulnro=45&thisissx=zuzzzla&lang=en
http://www.npp-rubin.ru/index.php?itsfltinside=1&fulnro=50&thisissx=zuzzzla&lang=en



Components of the IADS of army air defense. In case of 9S932 Barnaul-T the quantity of the commanded vehicles are inaccurate. The point of the diagram is the structure of the IADS. The 9S737 can be used as a cheaper option instead the Barnaul-T.

Not only the 9K33 Osa (SA-8) but the 2K12 Kub (SA-6) also had datalink connection regardless each battery have SURN with target acquisition radar with 360 degree scan capability. The connection provides advantage because without using the target acquisition radar can be prepared for engagement. Because both the fire control and target acquisition radar are on the same vehicle a successful anti-radiation missile employment can destroy both of them.

For each Kub regiment was assigned a 9S44 K-1 Krab system which previously served as a command post for S-60 AAA regiments as well as S-75M Volkhov batteries. [83] The two main equipment of the Krab were the 9Sz416 KBU (fire control cabin) and the 9S417 KPZ (target coordinates receiving cabin). The Krab was able to command and coordinate of the work of five Kub batteries and was able to forward the parameters of ten targets. The command system was able to receive from data from P-10/12/15/18/19 and the P-40 complex and could forward to Kub, Krug or SON-9 units target coordinates. The 9S417 was assigned on the "receiver" side for example to a 2K12 Kub battery.



Above left is the 9SS416 KBU (fire control cabin), above right is the 9S417 KPZ.

[83] http://www.flak11.de/AFLK%20K1.htm

The 9S52 Polyana-D4

The 9S52 Polyana-D4[84] has been mentioned in the chapter about 9K37M Buk-M1 system. This vehicle is not only the command post of an Buk-M1 battalion but it also coordinates the work of Buk-M1 (M2 or M3 variant either) and S-300V/VM brigades. Moreover it was the first joint command post which could establish connection both with army and homeland air defense units as well as with Beriev A-50 AWACS (today A-50M or A-100).

The Buk brigade itself does not has its own unique brigade level command post such as the 9S457 KP as the S-300V brigade. The Polyana-D4 fulfills this role besides being a "hub" which forward target data for lower level units.

The 9S18M1 Kupol radar of the Buk-M1 battalions is not the best fitted for detecting and tracking ballistic missiles therefore the Buk brigade relies mostly on the dedicated ABM radar of the S-300V.

According some sources the Buk-M1 variant did not had ABM capability at all but Finnish crew during the final live exercise was able to shoot down sort ranges ballistic missiles at the first attempt. The Buk-M1-2 has ABM capability as well as later variants.

In case of a large scale conventional war between the NATO and the WPACT very likely the four battalion of the Buk-M1 brigade would be dispersed along the frontline. This made pointless the close coordination considering only the Buk-M1 itself. Rather they would work together with S-300V. Very likely this is why the Buk family does not have even today an own command post and also does not have a brigade level long rage target acquisition radar as the S-300V. Because the ***9S15 KO Ozbor-3*** (Bill Board) act like this.

The first Buk-M1 brigade entered in service in 1987. Even at the end of Cold War only three S-300V brigades existed (Kaliningrad, Ukraine, Moscow) and only two Buk-M1 brigades (one in Hungary, one in East Germany). The aimed full capability became available long after the Cold War because of the limited operational capability of the very early A-50 variant. The Polyana-D4 in fact is an army gruop level command post. The extent and function of the digital datalink capability of the 9S52 is similar to the American TADIL-J datalink.

This limited quantity had quite a serious impact about the S-300V and Buk-M1 capabilities as well as on older SAMs. Because normally each army group[85] has one brigade S-300V and the two armies 1-1 brigade BuK-M1. This mean the Buk-M1 in Hungary did not have the radar of the S-300V while the S-300V in East Germany without the BuK-M1 did not have the Polyana-D4. In this case such level of datalink connection

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84 http://pvo.guns.ru/asu/polyana_d4.htm , http://roe.ru/eng/catalog/air-defence-systems/polyana-d4m1/

85 *This is a level in military organization typically is consisted by two armies, sometimes three. We can it also army group. The structure and organization of the Soviet and WPACT forces is explained at the beginning of the army air defense chapter.*

between lower level units (down to the SHORAD units) was not available as would be both in the same army.

The function and role of A-50 AWACS is not exactly clear in the commanding interceptions and commanding of fighters. It is sure the A-50 is able to forward data to both for army air defense units and homeland air defense.

Very likely the operators on the A-50 were not aware about the fighters ready to intercept on the ground and about reserves (either fighters or SAMs) only the higher level ground units of the IDAS.

Comparing to E-3 Sentry the early A-50 maybe was just a different type of radar in the IADS system but not a high capacity command post for intercept operators. The most likely route of the data flow and the command chain is the A-50 → ground based IADS systems → target coordinates to fighters.

Below is a gallery about the Russian command posts and systems:

http://www.ausairpower.net/APA-Rus-ADCP-CP.html

Threat of drones and UAVs and UACVs[86]

In the latest two decades emerged and became (quite) widely used UAVs from the smallest quadcopters up to the largest such as the Global Hawk.

Thanks to the more and more advanced digital electronics it became possible to design such flying vehicles which can carry lightweight digital camera systems. The drones nowadays can fly without direct human control using only inertial navigation system (INS) + satellite (GPS or similar) navigation without receiving regular input via radio. Comparing to direct radio controlled (RC) vehicles this makes a lot more easier to use them well and safely. Not only small helicopters and quadcopters but conventional flying airplane like drones can be used by operators without special piloting skills. Many times these new tools does not require regular radio control input from the operator.

The main problem are the size and engine of the UAVs which makes hard in many cases their detection and destruction. Even just detecting these lightweight and very small flying objects is a not an easy task. Because of their small size – some of them have less them 0.5-1 meter main dimension (R <0.25-0.5 m) – and quite silent electric motors is very hard to detect them. Even if it uses small piston engine the emitted noise is nowhere close to conventional airplanes of helicopters. From few hundred meters they are undetectable by noise with human hearing.

Also thanks to their composite structural material with very few metal components their radar cross section is small and it is especially small of the RCS of small quadcopters.

Because of the electric or small power combustion engine even with IR cameras is hard to spot them. Comparing to jets or turbo-propelled driven aircraft which produce lots of hot flue gas the electric driven UAVs with 1-10 kW engines literally does not produce waste heat. The surface of an electric motor can be hot for human touch but even 50-100 C surface temperature is nowhere close to 500-1000 C gas temperature (plume) of jet or turboprop engines. The 10-100 kW combustion engine driven aircraft are also harder to spot because the IR signature is smaller to human piloted aircraft.

Above left is a very small quadcopter above right is the MQ-9 Reaper UACV. The drones in size similar to MQ-9 are not an issue for a good army air defense. They are enough big for radars and engine produces enough exhaust gas to be downed by IR or radar guided missiles. IR SHORAD has engagement range up to 3-4 km altitude and 4-6 km range while the radar SHORAD can have 6-10 km maximal engagement altitude with 10-20 km engagement range. The latter SAMs can act as area denial against MQ-9 category drones. Such kind of target are enough large for proximity fuse of the missiles.

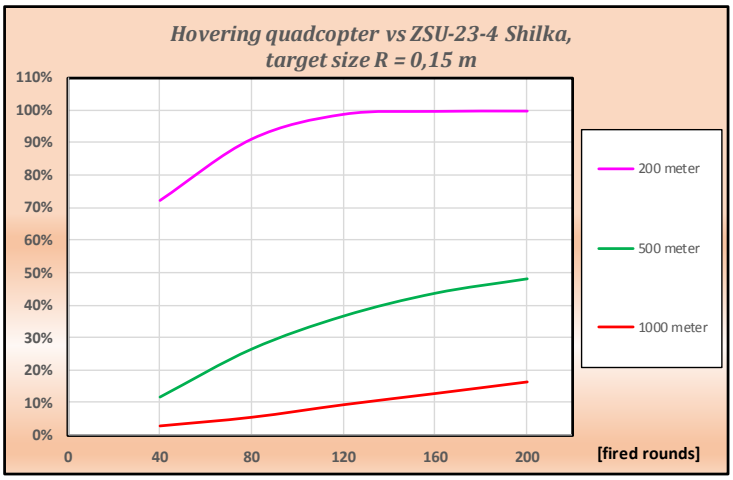
86 *Unmanned Aerial Vehicle, Unmanned Aerial Combat Vehicle*

The more and more serious issues are such small drones similar what we can see above left. They are way too small for any conventional air to air missiles and even for MANPADs.

The size and physical properties of very small UAV currently strongly limit of the available defensive options with currently available equipment. The conventional anti-aircraft guns were designed against helicopters and airplanes which are mostly one or even two scale larger targets comparing to drones or very small quadcopters.

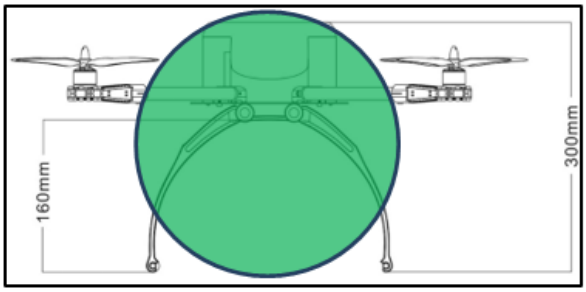
Even against human piloted fast flying airplanes hundreds of rounds are needed for high kill probability at long range. Using the 2K22 Tunguska, Flakpanzer Gepard and similar AAA equipment is close to zero the chance of hit against very small quadcopter at reasonable distance because of the random dispersion of the guns. For example, the 23 mm gun of the ZSU-23-4 Shilka has the following parameters.

Flight time [s]	Distance [m]	Velocity [m/s]	Dispersion (CEP)[87] [m]
0	0	980	0
0.2	200	860	0.4
0.6	500	700	1.2
1.4	1000	520	2.8
2.5	1500	400	5
4.17	2100	310	8
5.5	2500	280	11



If we assume a target of a small quadcopter with D = 0,3 meter size (see of the right) only at 500 meter target distance the probability of a single hit is only about 50% target with a 200 rounds (this means about 4 seconds long) burst.

At 1000 m the calculated chance to hit is less than 10%. Even for this low success rate engagement we have to assume that a Shilka or similar AAA system is able to track continuously very small targets, there is no aiming error, target does not move and operator does not react on the air defense fire, etc...[88]



On a video[89] we can see even at 100 meters distance on a short burst the dispersion of high rate of fire 2K22 Tunguska system. A very small drone with R = 0,15 m main dimension would survive the short burst (with about 40 rounds). The Cold War and legacy AAA systems were designed against airplanes and helicopters and not against very small drones. These kinds of targets are enough large to make sufficient the guns with high rate of fire considering their dispersion while they use cheap rounds with impact fuse.

87 https://en.wikipedia.org/wiki/Circular_error_probable

88 *In Hungarian was made a very long article by me about modeling of AAA systems against different kind of targets with statistical mathematical model based on known parameters of same AAA systems. The source if the diagram and the values is that document. Maybe one day it will be translated into English.*

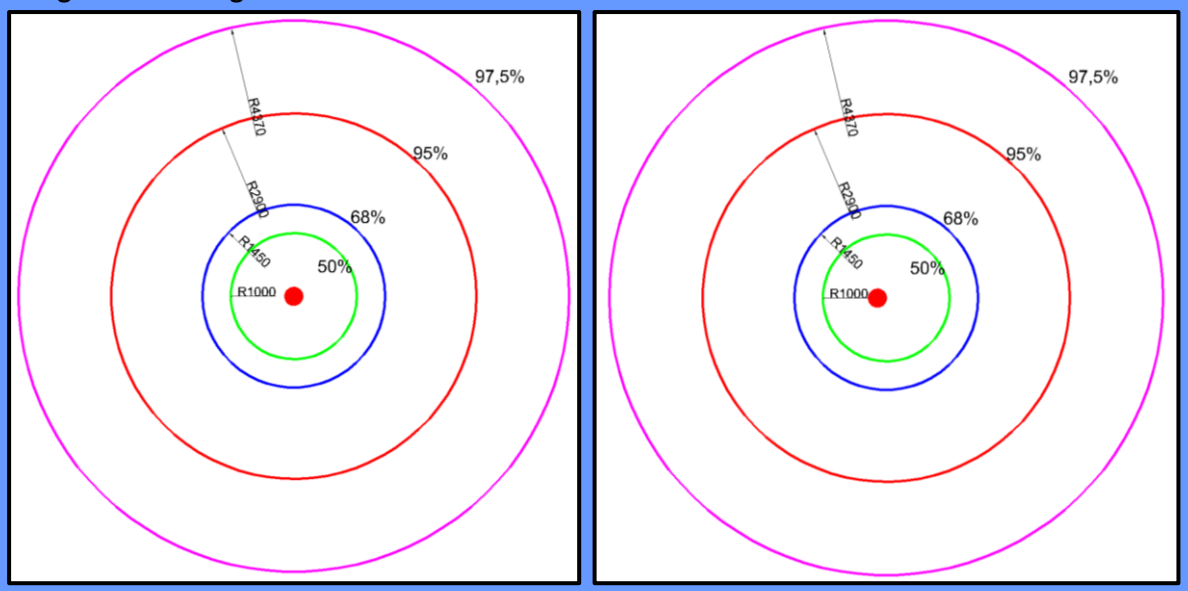
89 https://www.youtube.com/watch?v=ruC4IhTxLgs&feature=youtu.be&t=369

The Cold War legacy AAA systems have problems even tracking small targets with radar. On a demonstration video Pantsir tracked optically the target not with radar.[90]

The effect of the dispersion comparing to aiming point. Is not a single hit closer than 15-20 cm from the center regardless the distance was only 100 meters. This dispersion is acceptable for shooting down airplanes but against very small drones is simply makes ineffective the air defense gun.

The demonstration of the Pantsir was very funny from the point of view who understand what exactly happened. The cause of being funny was the off aiming at the beginning of the video because in reality it did not have any effect on chance to hit. Target distance was about 400 meters.

The dispersion of the gun is so large at 400 meters the very minor off aiming does not have any effect of chance to hit. The dispersion (CEP = circular error of probability, it is the radius where 50% of shot are) of the Pantsir is similar to ZSU-23-4 Shilka which is about 0,5 meters at 400 meters of distance. This means about 50% of rounds will hit within this radius bit **it also means the total dispersion radius is about 4 (!) times larger considering characteristics of the bullet distribution**.



Moving off a bit the aiming point because of the large dispersion radius was **totally meaningless** as we can see in the drawings above. The percentage values show the confidence level at certain radius from the center of dispersion. On the drawing above right the small quadcopter size "target" is moved off from a center a little bit. This what happened in the video. The target remained still almost the center of the dispersion **which means the chance for the hit is virtually remained the same regardless of the off aiming**.

90 https://youtu.be/pdmBBaTQ6q0?t=1351

Even for first attempt with a 40 round salvo was achieved a hit on the leg of the drone what could survive. The first hit on the leg was **a very, very lucky and unexpected** event but and after shooting about 160 more rounds happened which was not so unlikely anymore especially against a stationary target.

Therefore, the drone later was not downed after *"the first volley of 40 rounds"* as the reporter said because many times were fired a 40 rounds long burst before the quadcopter was destroyed. In fact, the model which I used predicts that chance to hit from about 200 shot at 400 meters is about 65%.

The case is similar to playing heads or tail game. Sooner or later will be balance between the two outcomes. In the case of this demonstration it could be predicted after how many shots is required for a certain confidence level of destroying the target. The video simply used this effect. Fired with off aiming and happened a very "unlucky" hit from the point of view of the demonstration. When finally reached the quantity of rounds when the fatal hit could be expected it could say they did it with "first attempt" the target. While in reality the drone was destroyed but not because of the "correction" of the off aiming. The video just proved two things:

1. Statistics is not an easy field of math without understanding the effect of dispersion and probabilities.
2. Shooting down a small drone with acceptable effectiveness with conventional AAA systems is simply not possible.

400 meter distance with current recon capabilities of drones is simply means way under estimated target distance. Drones can provide good quality image from much larger distance which means even more longer engagement time and ammo is required for destroying a single hovering quadcopter.

Shooting down UAVs and small quadcopters at acceptable distance is also not possible also with small arms, rifles and machine guns. On a video[91] we can see how likely is the hit and kill on a drone which flew minutes ahead of many, many gunners.

The conclusion is different kind of equipment are required against the threat of recon of suicidal drones/loitering munitions.

Regardless very small drones can stay airborne for a short time with limited operational range (30-60 min, 0.5-5 km with Wi-Fi 2.4 GHz remote control but they can fly 30-50 km in autonomously) they can provide essential intelligence data in real time. Some drones is able to operate even at night with infra-red cameras. These drones are very helpful to create a good situational awareness on the battlefield.

Even just because of the recon capability it makes desirable to destroy the drones instead just jam or disable them with electronic jamming. Sooner or later suicidal drone swarms can be the threat[92] which can perform coordinated strike against unarmored or lightly armored vehicles. In case drones will become even more cheaper and intelligent every single soldier can be hunted by small drones. This is not a joyful vision of the future...

[91] https://www.youtube.com/watch?v=rGLxKXtkHpY

[92] https://www.youtube.com/watch?v=DjUdVxJH6yI
https://youtu.be/-HZHRTEYTVq
https://youtu.be/8FukTsKmXOo

Considering what we can see on the drone swarm video it seems feasible to create such an aircraft carried pod or cruise missile which can carry lots of small drones. A fighter aircraft or a cruise missile such as the Taurus KEPD 350 under the radar horizon could carry the drones enough close to target. The target for example can be an S-300/400 battery. From 30-40 km the target the drones can be released depending from the terrain.

The currently used air defense systems are not capable to destroy such high quantity of very small targets. Even if they could it is not economically viable. Only about 2-4 fighters or half a dozen cruise missiles could release 50-100 small drones.

These small drones would not be able to carry more than 1 kg warhead but this is more than enough to damage or even destroy the fire control radar and other crucial system elements of theS-300/400 the battery. Without the fire control radar the combat potential of and S-300/400 battery (or similar Patriot) is zero . If the fire control radar has been disabled the battery could be destroyed with conventional weapons if it is not protected by Pantsir, Tor-M1 or other similar system. In case the S-300/400 battery has these short range SAMs for protection at least much less firepower is enough to penetrate the remaining element of the IADS but the area denial capability by the S-300/400 is disable for a while...

Of course, such drones require some kind of EO/camera to find their targets and some kind of “AI” for target recognition but on current technology level this is not sci-fi anymore.

The imagined scenario above is nice but if the S-400 SAM had over the horizon capability it would (partially) eliminates the concept. In case the terrain makes possible for the long range target acquisition radar the early detection or AWACS is available with data link the “mothership” fighters and cruise missiles can be attacked and downed even before they reach the 30-40 km, the range limit of ordnance release location. (S-400 + A-50U/A-100 will be able to launch under the horizon as well as S-350 Vityaz. This is not unique Patriots with AR guidance also will be able to do this.) This means much gong range drones would be needed. But cheap drones for swarms are on the opposite side of the scale where larger drones are sat. Both cannot be done in the same airframe...

So, in the near future it may be possible dealing some “soft” targets with swarm of small drones to prepare the battlefield for conventional weapon systems but using as a general strike weapon is another thing. They are too small and have too small range against many targets. Many types of targets are to armored or is too fast (helicopters and airplanes) to be able to intercept them. Regardless they may not able to destroy a tank or infantry fighter vehicle they are able to downgrade their combat potential by destroying their sensors. This means even a less advanced tank can deal with more advanced what lost its full potential. The drones can change the balance between the fighting sides.

The task is given. The currently used small drones and quadcopters and within the foreseeable future smaller drone swarms have to be dealt by air defense. The drones likely will challenge the capabilities of air defense. It is not feasible to counter or destroy every small drones with MANPADS with 50-100k USD cost/missile or even more expensive missiles. Comparing to these most of civilian small drones are far more cheaper. Of course most of civilian does do not have jam resistant communication.

The loiter capacity ammunitions (LAMs)[93] are in the minds of designers since the early '90s. They were part in the Future Combat Soldier program as NLOS-LS (Non-Line of Sight Launch System).[94] The whole FCS was cancelled including the special munition because of its high cost at that time. The demand for such drone is dated back decades but nowadays it seems to possible to design such system with an acceptable price tag.

The civilian drones can be used as an alternative regardless they not met with the specification of the NLOS-LS LAM (72 km range and 30 minutes loiter time) but with 20-30 minutes max. flight time they are better than nothing. The weakest point of LAM drone swarm is the in between communication of the drones. In case the connection is broken or jammed the drones may can fly and find their targets only autonomously based on last target coordinates and their camera system but this needs a very advanced software.

The civilian drones mean a considerable threat because they are available for a very small price and many armed forces in the word are not (yet) well prepared against them. They are ideal tools for COIN/low intensity conflict environment.

Even professional armed forces many times rely on civilian drones because they are easily accessible and the information and recon data what they can provide in many cases is almost identical or identical what military drones provide.

An RQ-11 Raven (on left) is a hand launched drone. It cost was little above 20 000 USD in 2017. The Raven before 2015 had only forward looking camera and because of its airplane like drone it has much restricted recon capability comparing to quadcopters or octocopters with rotatable cameras. Since 2015 RQ-11 can be equipped with a better camera system but it made even more expensive the drone. Similar civilian drones or small quadcopter in some cases cost only a fraction of the RQ-11.

Against drones mostly electronic jamming are used especially against civilian ones which are not protected. The problem as the drones become more advanced as less will be useable the jamming if drones will be able to navigate using inertial navigation (current gyroscopes even is smartphones are enough good for short time) combining with terrain/shape recognition. Of course, GPS or any satellite navigation system can be jammed. But in this this kind of navigational aid for the jammer also may be unavailable for the jamming side either.

For jamming the drones relatively large and heavy equipment is needed. The handheld jammers has only some dozens of meter range. Another issue is the frequency. Currently drones uses the 2.4 GHz frequency range. The armed forces can be equipped with the necessary jammers... then maybe somebody start to build drones which uses different band range. Even every kind of jammers are supplied the friendly forces it can jam the short-range communication devices and well as civilian cell phone communications which is unacceptable in some situations.

Because of the side effects and only preventive mode of the jamming it would be better do destroy the drones. This could be done with smaller or cheaper missiles, guns with special munitions (AHEAD[95] or airburst) or maybe with energy (laser) weapons and the last option is using the hunter drones.[96]

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93 https://youtu.be/1tZB44fL5tw , https://youtu.be/qIYZiTqenJs
https://dronecenter.bard.edu/files/2017/02/CSD-Loitering-Munitions.pdf

94 https://en.wikipedia.org/wiki/XM501_Non-Line-of-Sight_Launch_System

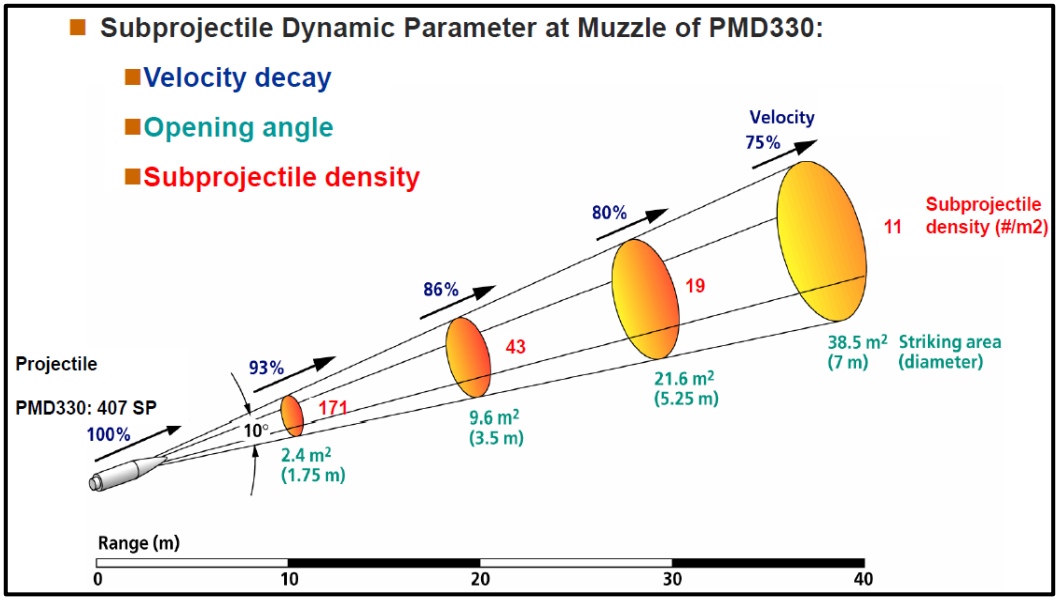
95 https://youtu.be/d0oHvqIUEmY

Luftvärnskanonvagn (lvkv) 9040, special variant of the CV90 IFV with anti-drone equipment.

Let's start with the guns. In the near future automatic or remote controlled gun turrets/stations can help the anti-drone warfare. Turrets with sensor also can be applied on infantry fighting vehicles, a self-contained system which consist 360 degree coverage optical and/or IR/EO seeker. The problem such kind of system cost hundreds of thousand USD without the gun and the vehicle itself.

Such weapon system is the special variant of the Sweden IFV CV90. For more than 10+ year Sweden developed the 40 mm Bofors gun with 3P programmable ammo but so far nobody has been ordered.[97]

Even more specialized and dedicated AAA system is the Skyranger (on the left) system with AHEAD ammunition which is the mobile version of the Skyshield system.[98] As on videos have been demonstrated it is able to track and destroy very small quadcopters from at least about 500 meters only with some rounds as well as larger airplane like UAVs either above 1 km (target was an MTX type drone).[99] Because of the technical requirement of the AHEAD technology so far has not been developed AHEAD type munitions smaller than 30 mm caliber. Against such small targets as quadcopters to achieve high probability of kill with short burst at least 30 mm but rather 35 mm size ammo is needed. Against larger target heavier submunitions also demand the 35 mm caliber.



The subprojectile density in case of different burst distances with 35 mm PMD 330 ammo.

96 https://www.youtube.com/watch?v=PpqFNSpANFM
https://player.vimeo.com/video/364333850, https://bit.ly/379OlGC , https://youtu.be/QwDykpIQkfc

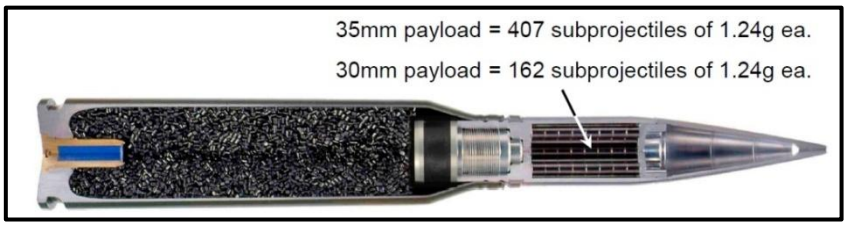
97 https://www.youtube.com/watch?v=Nj0q-sxKrvg

98 https://youtu.be/h3zhkpVsn28
https://planesandstuff.files.wordpress.com/2014/05/janes-system-upgrades.pdf

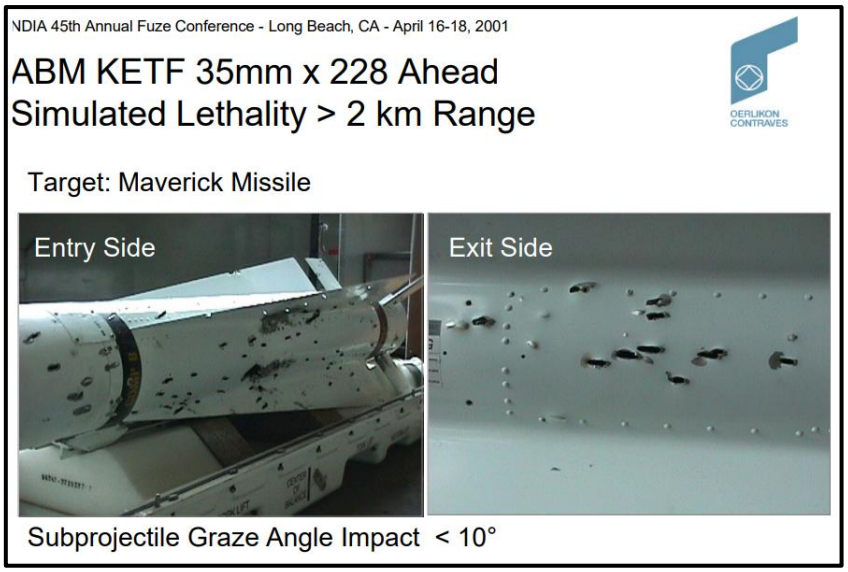
99 https://www.youtube.com/watch?v=h3zhkpVsn28&feature=youtu.be&t=117
https://www.mtx.pmrobotics.ch/

Designation	Payload	Weight of sub-projectiles
PMD062	152	3.3 g
PMD330	407	1.25 g
PMD375	860	0.64 g

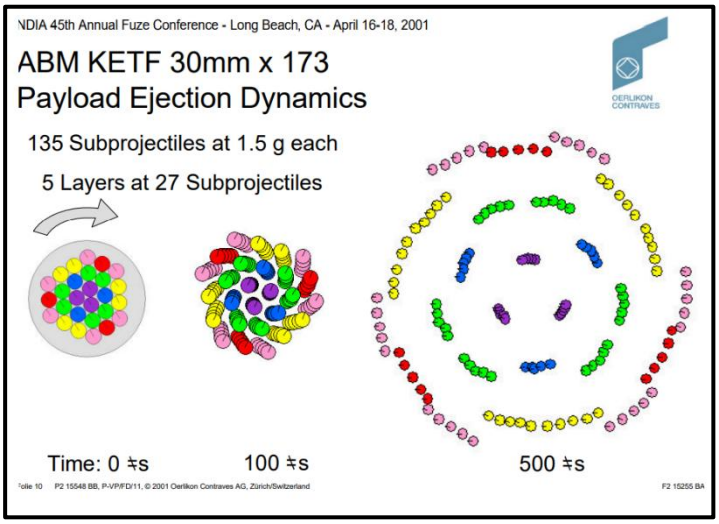
AHEAD ammo types in 35 mm caliber.[100]

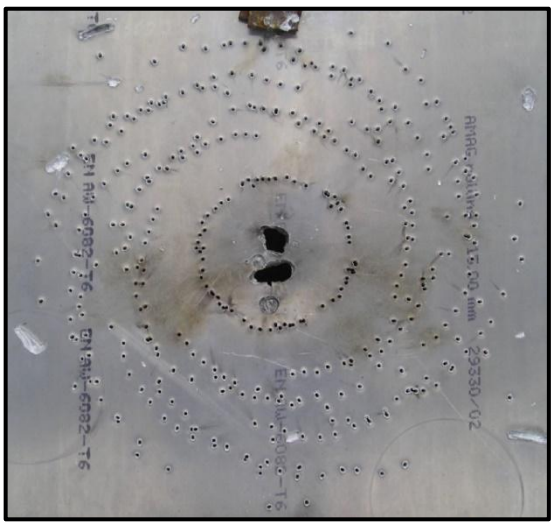


Difference between 30 mm and 35 mm in subprojectile quantity which has strong impact on projectile density.



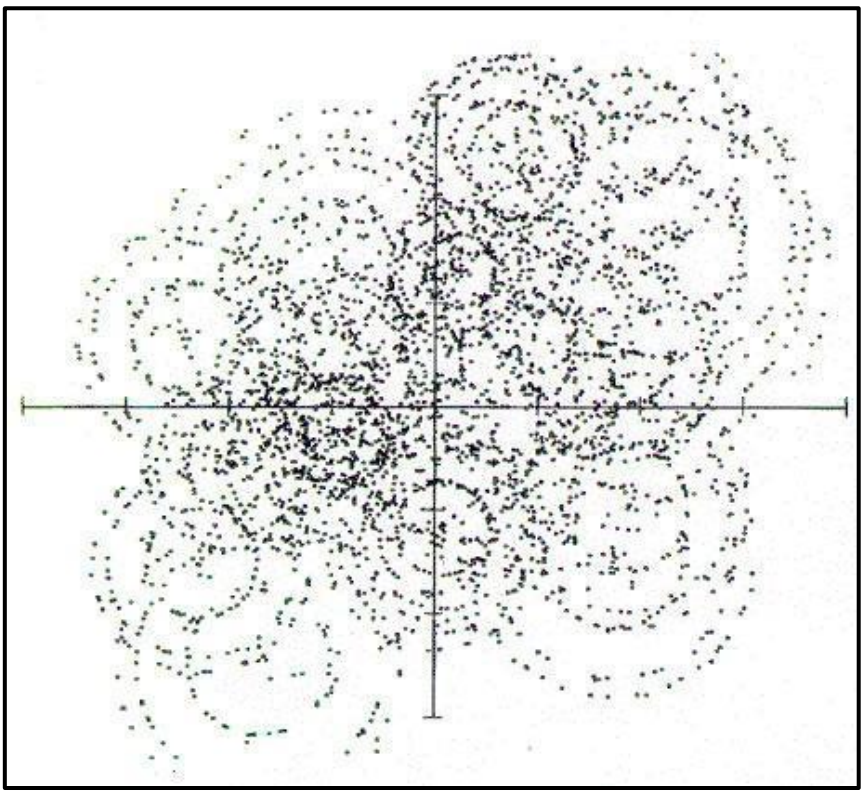
The diameter of the AGM-65 Maverick missile is only 0,3 m. Even at about 2 km distance some rounds can cause such extensive damage on the missile. Similar system to Skyranger installed on ships as CIWS would outclass any older conventional high rate of fire system such as Phalanx CIWS or any similar.





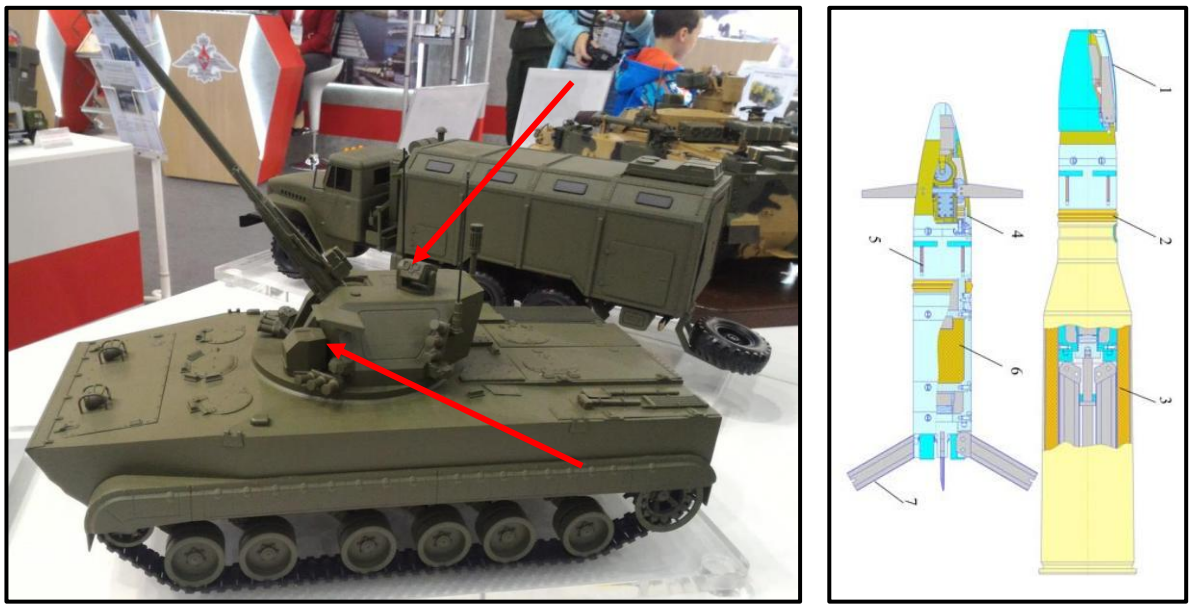
The dispersion characteristics of the 30 mm-es KETF ammo (above left) and the 35 mm (above right).

100 https://apps.dtic.mil/dtic/tr/fulltext/u2/a393758.pdf
https://ndiastorage.blob.core.usgovcloudapi.net/ndia/2011/gunmissile/Tuesday11786_Bradick.pdf
https://ndiastorage.blob.core.usgovcloudapi.net/ndia/2009/gunmissile/7923paulissen.pdf



The covered area with the Skyguard / Skyshield system with 25 round salvo (about 1,5 sec long) using 35 mm ammo.[101] There is simply no way to survive such subprojectile density. The scale of the drawing are meters, the crosshair covers 4x3 meter. Regardless of the dispersion of the gun at longer range the subprojectile density is enough big to destroy anything only with about 1-2 dozen rounds comparing to conventional AAA system which cannot achieve a even a single hit on target even with hundreds of rounds.

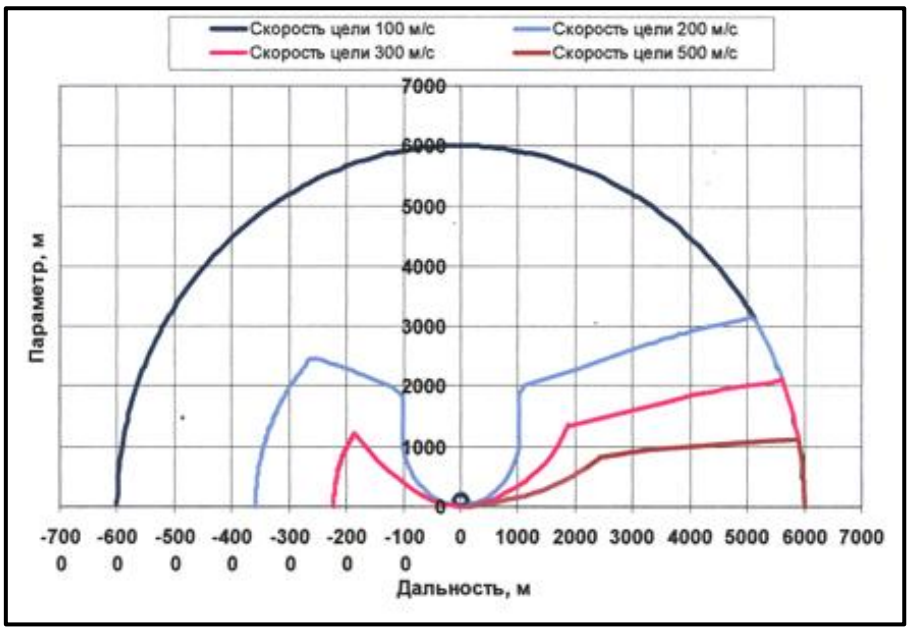
There are also other concept against drone with multi-purpose capability. Based on BMP-3 infantry fighting vehicle (IFV)[102] with a 57 mm gun and radio fuse laser beam riding ammo was developed the 2S38 Derivatsiya ZAK-57.



2S38 Derivatsiya, new turret & gun with the necessary electro-optical equipment and the intelligent ammunition.

101 http://www.repulestudomany.hu/kulonszamok/2007_cikkek/nagy_norbert.pdf
https://bit.ly/2Wxan3L

102 https://goo.gl/H8QhAQ, http://www.military-today.com/artillery/2s38_derivaciya_pvo.htm



The engagement zone of the 2S38 Derivatsiya, system.

The conception of the 2S38 makes possible using a single unit against drones, helicopters and even against other IFVs. The latest and most advanced IFVs are quite well protected against 25-30 mm automatic guns (except close range engagements) therefore the new long range and guided munition can provide range and accuracy advantage comparing to IFVs equipped with conventional 25-30 mm autocannons.

Another benefit of the 57 mm caliber for the ammo not only being "intelligent" but with such size is possible to cause such damage which exceeds smaller gun calibers. Because the ammo is guided it has pinpoint accuracy up to max. engagement range comparing to conventional guns which has (natural) dispersion. The dispersion (CEP value) of conventional 25-30 mm autocannon at 1000 m is about 0,5-1 miliradian (mil). This means APC/IFV size targets rarely can be hit above 3 km distance even about firing two dozen of rounds. The armor penetration capability of the 25-30 mm rounds is low comparing to frontal armor of IFVs.

As we can see on the engagement diagram above with zero offset distance at low level in theory even airplanes can be engaged up to 300 m/s (M0,9) speed up to 2-3 km altitude and 6 km distance which is close to engagement zone of the older MANPADs. Against helicopters (up to 100m/s) the 2S38 has very similar only a slightly smaller engagement range than 2K22M Tunguska which means it has almost the same area denial capability. Against low quantity drones the 2S38 Derivatsiya seems a suitable solution especially it is a multipurpose vehicle. The intelligent 57 mm round does not have to produce a direct hit because it can have airburst warhead either while it retains the pinpoint accuracy.

There is a strong trust and hope in energy weapons. Solid state lasers can be used in good conditions at least against small drones today.[103] In military exercise and demonstrations some lasers have been proven[104] but they have not been deployed on battlefield in real conflicts. Currently is about 20-30 kW lasers are available where the cooling and portability is solved but even such low power lasers (comparing

[103] https://www.raytheon.com/news/feature/laser_dune_buggy.html
The vehicle does not have an armored operator compartment which makes undesirable in a combat environment but at least is light and any helicopter of transport aircraft can carry. https://youtu.be/IiEXkqIbKsY

[104] https://bit.ly/3397C7M

to need for other targets) are very expensive. Another problem their performance is limited by the weather.

On smaller scale handheld equipment is also available such as the Pike[105] system. The Pike missile is launched from a handheld grenade launcher. The missile is laser guided the illuminator is attached on the launcher. The missile is semi-active laser guided the target has to be illuminated continuously which requires certain manual skills from the operator to keep the laser beam on the target during the whole engagement.

The weight of the missile is 0.77 kg (without the launcher tube), warhead weight is only 0.27 kg, length of the missile is 43 cm (16.8 in) According to manufacturer its rage is 2 km but it is hard to imagine than any operator can aim and hold on moving targets the laser for longer time. The missile kinematic range likely far outranges the limitation of the aiming.

The Pike missile and one possible launch mode with a handheld grenade launcher.

Currently it has not seen on vehicle mounted version of the Pike but in theory it would be a usable solution installing a complete automatized system on tanks or IFV. At first step it would solve the issue if target tracking with laser. The carrying capacity of these vehicles are sufficient for installing small turret which can be equipped with the necessary EO/IR sensors and some (about 6-12) missiles on each turret.

These extra sensors are required besides the base sensors of the combat vehicles to ensure the automatic search and track capability while the vehicles still retain of its original combat potential. It is possible that an existing system has to be sacrificed in exchange this anti-drone system (for ex. remote controlled machine gun) but in case 1-2 modified tank or IFV can ensure the protection of a company size unit (about 10 tanks or IFV) this tradeoff seems acceptable.

[105] https://www.raytheon.com/capabilities/products/pike/

Summarizing all the mentioned issues and solutions above:

- The civilian and small military drones are means larger and larger threats especially the upcoming drone swarms and suicide killer drones.
- So far universal hard kill protection against drones are not available currently mostly electronic jamming is used (soft kill).
- The currently developed systems try to deal with threat the following ways:
    1. Intelligent munitions, rapid fire combining with AHEAD or airburst ammo up to 40 mm caliber down to 30 mm.
    2. Intelligent guided munitions.
    3. Energy weapons / microwave weapons
    4. Smaller and cheaper missiles comparing to conventional anti-aircraft missiles because currently available Cold War legacy systems are too expensive for the goal and their capability is limited in many areas.
    5. hunter drones
    6. electronic jamming